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BMFT Subsidy Plan for LASER 2000 Project 1993-1997

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[Foreword, table of contents, 12 chapters, 4 appendices from book "LASER 2000: Subsidy Plan 1993-1997," Federal Department of Research and Technology, Report on Public Work, Bonn, March 1994, 69 pages, ISBN: 3-88 135-277-5, captioned photographs omitted]

Germany: BMFT Subsidy Plan for Laser 2000 Project 1993-1997

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[FBIS Translated Text]

Foreword

Laser technology is among the strategic technologies of our economy. Its significance as a key technology is primarily in its increasing influence on almost all areas of technology, natural sciences and medicine. Laser technology is expected to provide strong incentives for innovation well into the 21st century.

In future, lasers will be used even more widely as energy carriers, as non-invasive tools, as ultraprecise measurement instruments and as process initiators. Their use will lead to new products, procedures and processes which will be characterized by greater environmental friendliness, quality and productivity. Thus zero error production can be achieved in procedures and processes by optical laser measurement and control methods. In the field of health care, medical laser methods will create new technologies which protect the patient and which are characterized by minimization of surgical intervention (minimally invasive therapy).

The main concern of the LASER 2000 subsidy plan is to keep Germany attractive as a site for laser technology research and production and to improve factors which affect them. Thus research subsidies are directed towards making laser technology capable of unfolding its innovative potential and towards making our companies capable of participating in the growth market in laser technology and creating new jobs.

Technologically, the LASER 2000 subsidy plan is primarily pursuing the goal of creating the conditions for a new generation in laser technology which will be characterized by the replacement of expensive tube technology by more efficient semiconductor technology.

In addition, the plan is concerned with application-oriented technological breakthroughs; in particular, the preliminary research for precision laser processing is to be augmented so that new processing methods and advances in quality for industrial production can be achieved with laser light as a tool which works without mass and without direct contact. New application fields are to be opened up by optical laser quality testing and new environmental technologies and by use of laser spectroscopy, which can be called upon in modern biology, for example, to reveal elementary processes in order to make them technically more accessible. In medical laser technology the goal is a significant contribution to minimally invasive therapy and use of the "optical scalpel," which will also shorten hospital stays and rehabilitation time for patients. Our attention will also be directed towards legal requirements, such as the normalization and standardization of security technologies.

Putting these goals into action will involve, on the one hand, obtaining new, fundamental knowledge of laser technology and, on the other hand, achieving well-defined contributions to solutions through interdisciplinary research, both fundamental and application-oriented, in pilot projects on certain problems, such as the new technological generation of lasers and new fields of application.

The main points and project topics contained in the present LASER 2000 subsidy plan have thus been worked out in an intensive dialog with leading representatives of business and science. This means that the measures envisioned are focussed on economic requirements and aimed at future markets, particularly in economic sectors where the Federal Republic's export strength lies.

Dr. Paul Krueger, Federal Secretary of Research and Technology

1. Introduction

Laser technology and laser applications can achieve a significant contribution to the enhancement of Germany's industrial standing and its economic "vital nerves" like industrialization and strong foreign trade ties.

Because of its influence in almost all areas of technology, the natural sciences and medicine, laser technology is among the indispensible key technologies of the future, which can bring about far-reaching changes for significant parts of the total economy (Fig. 1).

In the period from 1987 to 1992, earlier subsidies laid down important foundations for industrial lasers and their applications. New scientific and technical developments and changing market trends require new focal points and strategic goal-setting so that Germany can continue to play a leading scientific and economic role in international competition in laser technology in the future.

The new LASER 2000 subsidy plan, which is to replace the BMFT subsidy plan "Selected Areas of Laser Research and Laser Technology," should do justice to this claim. Important aspects will be further developed and new contents for subsidy policy measures will be used as a foundation. This should bring about a significant contribution from laser research and laser technology to the technologies of the 21st century.

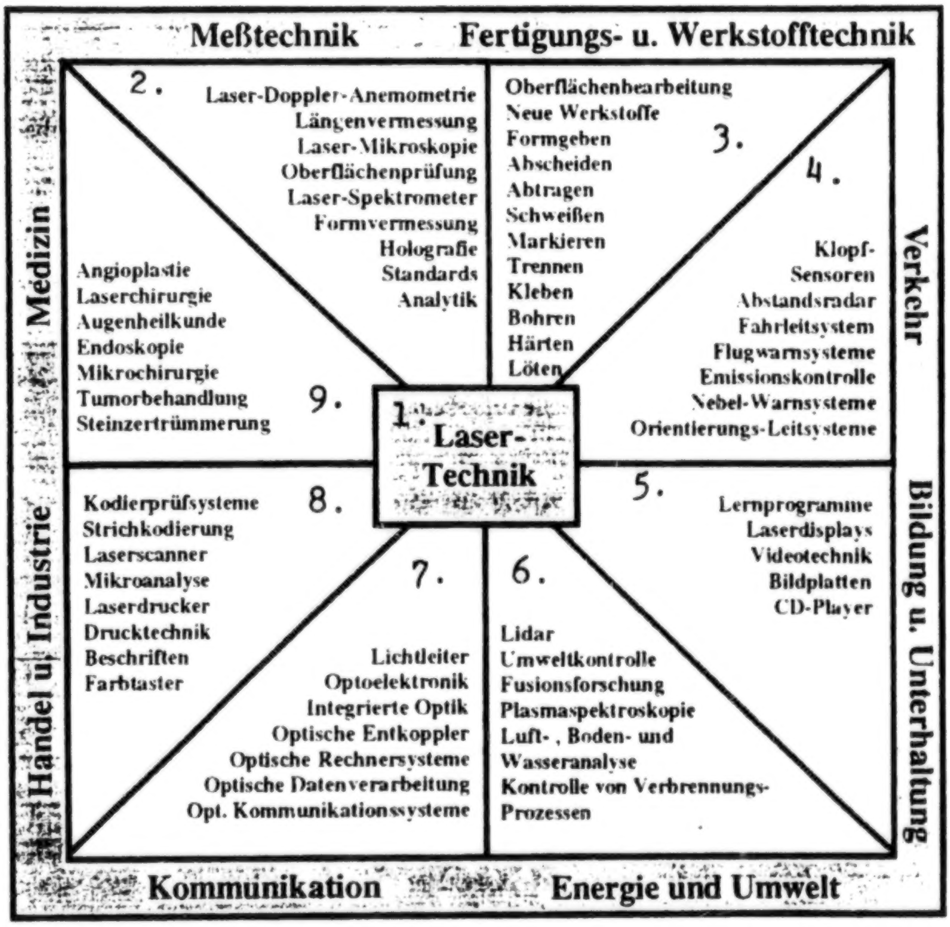

Fig. 1: Applications of laser technology, general overview. (Source: Fraunhofer Institute for Laser Technology, Aachen, VDI Technology Center, Duesseldorf)

Key: 1. Laser technology.—2. Metrology. Laser Dopppler anemometry; linear measurement; laser microscopy; surface testing; laser spectrometers; form measurement; holography; standards; analysis.—3. Production and materials technology. Surface processing; new materials; molding; refining; removal; welding; marking; ablation; adhesion; boring; tempering; soldering.—4. Traffic. Touch sensors; intervallic radar; driving guidance systems; aircraft warning systems; emission control; cloud warning systems; orientation guidance systems.—5. Education and entertainment. Learning programs; laser displays; video technology; image discs; CD players.—6. Energy and environment. Lidar; environmental control; fusion research; plasma spectroscopy; air, soil and water analysis; control of combustion processes.—7. Communications. Lighting circuitry; optical electronics; integrated optics; optical decouplers; optical computer systems; optical data processing; optical communications systems.—8. Industry and commerce. Encryption testing systems; line coding; laser scanners; microanalysis; laser printers; print technology; lettering; color sensors.—9. Medicine. Angioplasty; laser surgery; ophthalmology; endoscopy; microsurgery; tumor treatment; kidney stone crushing.

2. Significance of the Laser and Its Applications

Technical innovations are among the most important means for assuring the competitiveness of companies and to develop international markets. Laser technology is now thought of in high-technology countries as a key crossover technology with a high level of innovation which points the way for the future. The significance of laser technology lies particularly in the possibility of creating novel technical solutions to problems and systems with high multiplicative effect: useful laser-specific information carriers, lasers as non-contact, non-tactile tools, as ultra-precision instruments with high spatial and temporal manipulability, as metrological reference objects and as process initiators.

Because of the many forms which lasers can take, the potential for applications and solutions extends to such important traditional branches of German industry as vehicle construction, construction of machines, tools and ships (Fig. 2) [not reproduced], the electronics industry, chemistry, increasingly also on biology and the medical and environmental fields (Fig. 3) [not reproduced]. The domain of the laser lies wherever precision,

flexibility and quality matter, but primarily in the opening up of new applications and less in the substitution of established techniques and processes.

A prerequisite for product visions and for quality enhancement in techniques and processes (e.g., for the "factory of the future") is the complete mastery of coherent light in all its properties. In future a new generation of lasers combined with the opening up of new application fields will be necessary. Photons are a tool of the future; their use will shape the processing techniques of the future comprehensively and fundamentally.

3. Summary and Strategy of Previous Subsidy Provisions

BMFT funding within the subsidy target area of "laser research and laser technology" in the period from 1987 to 1992, with funding of approximately 262 million German marks [DM] (not including laser uranium enrichment) led to the construction of an effective, professionally and regionally balanced research environment and in some areas to technological breakthroughs with high innovative potential for lasers, laser system technology and laser applications (Fig. 4) [not reproduced].

Besides the subsidy target area, "Laser Research and Laser Technology," there are BMFT subsidy programs which have laser research components, but are oriented strictly towards program or project objectives. These include, for example, programs and target areas such as photonics, materials research, health research and satellite communications, as well as satellite-supported geographic research, which involve both the adaptation of preexistent laser systems already available commercially and, to some degree, the development of laser systems for special applications. Support for topics relevant to lasers is also supplied by departments of the Laender and the Commission of the European Union. The appendix will provide a survey of BMFT programs which have laser components, and subsidy provisions of the Laender, the German Research Association and the European Union.

3.1 Previous Subsidy Target Areas and Funding

Previous subsidies in the context of the subsidy plan "Laser Research and Laser Technology" formed the basis of the target areas and expenditures shown in Table 1:

Laser material processing was clearly in the forefront of funding. In total approximately 72 percent of funds were apportioned to projects related to laser material processing (beam sources, components, systems, processes). In retrospect this prioritization was strategically correct and necessary in view of the significance of laser material processing for numerous traditional German branches of industry.

Table 1: Previous Thematic Target Areas and Funding (1987-1992) Under the Subsidy Plan "Laser Research and Laser Technology" (Source: VDI Technology Center, Duesseldorf)

Subsidy Target Areas	Funding (in million DM) 1987-1992	Percentage of Total Expenditure
Laser beam sources and components	96	36.6
—Power enhancement and process adaptation in existing laser types		
—New lasers		
—Laser components incl. materials and equipment technology		
Application technologies and systems integration	128	48.9
—Procedural basis for material processing		
—Fundamental research on linkage between laser properties and processing requirements		
—Laser devices for use in medicine		
Laser measurement technology and laser analysis	32	12.2
—New measurement applications with high innovative potential		
—Laser-supported analysis procedures and equipment		
Other, incl. technology transfer and evaluation of implications of technology	6	2.3

3.2 Goals and Goal Attainment of Previous Subsidies

Previous funding was intended to achieve three goals:

1) Construction and development of an R&D infrastructure in institutes in the area of application-oriented laser research.

This goal was completely realized for the previously funded target areas in the preceding subsidy period:

The BMFT subsidy provisions contributed to the formation of an effective, professionally and regionally balanced research environment in the area of application-oriented laser research in the area of the old Federal Republic, where the founding of numerous institutes were primarily the responsibility of the Laender where they were situated and of businesses in the private sector. About 900 employees (primarily natural scientists and engineers) are working on the broad and heterogeneous spectrum of laser research projects in 9 large laser centers and other non-university research institutes, six institutes of the large research organizations (FhG [Fraunhofer Society], MPG [Max Planck Society], GFE), and about 30 primarily small research groups in college institutes.

This laser research environment is being complemented in the new Federal Laender by about 20 strongly diversified non-industrial research institutes.

2) Strengthening of the technological basis and thus of the international competitiveness of the laser industry.

This goal was achieved in some areas:

In certain areas, as in CO_2 lasers in the 1-5 kW power range and in excimer lasers, German manufacturers attained a leading position in the international market. In solid-state lasers, German occupies an intermediate and in some cases a subordinate position.

3) Availability of laterally disseminated applications information

This goal of earlier funding could only be achieved in part.

Within systematically organized joint projects, the procedural basis for important industrial processing technologies (e.g., cutting, welding) were worked out (Fig. 5) [not reproduced]. But so far these have not found widespread use, particularly in small and mid-sized companies; for example, the level of diffusion for laser material processing is now only 20 to 30 percent of the application potential. Besides unaffordability and an insufficient level of technical readiness, the IFO Institute [Institute for Economic Research] in Munich particularly identified information barriers as stumbling-blocks (IFO 1990, [1]).

3.3 International Cooperation

A significant share of previous funding (approximately 25 percent) has been apportioned to international projects of the Eureka technology initiative. Target areas have included the Eurolaser projects, in which fundamental research on high-power lasers and their application in material processing is being done. New Eureka projects have been added since 1991: the investigation of laser safety in medicine and material processing. The primary goals of the Eureka-Eurolaser initiatives were to strengthen laser technology in Europe as a whole and to provide a European counterweight to Japanese efforts in laser technology. Both these goals have essentially been reached.

The Eurolaser initiative has allowed almost all European countries to develop significant forces—even small countries like Denmark, Greece or Austria. So far, there has been no Japanese export offensive of socalled "cheap lasers." The important German laser manufacturers have profited from the Eurolaser initiative. At this point laser use has a relatively high standing in Western Europe. There is also international cooperation with the CIS, the PRC and Israel and Canada (Fig. 6).

3.4 Structure of the Laser Research Landscape in the New Federal Laender (NBL)

As the laser research landscape in the NBL was formed, two laser institutions were newly founded within the framework of joint research subsidies by the Federal Republic and the Laender. These were the "Fraunhofer Institute for Material Physics and Layer Technologies" in Dresden and the "Max Born Institute for Non-linear Optics and Short-time Spectroscopy" in Berlin, as Blue List establishments. Project funding from the BMFT target area "Laser Research and Laser Technology" made it possible for outstanding research groups in the NBL to be supported very early on (Fig. 7). At this time approximately 26 percent of available funding is being used for this purpose. Centers of laser research were created in Berlin (laser beam sources and components, laser medicine, non-linear optics, spectroscopy), Dresden (laser material processing, new application technologies), Jena (optical components, laser material processing), Halle (laser material processing, quality control) and Rostock (laser applications in shipbuilding).

International Cooperation in the Area of Laser Research and Laser Technology

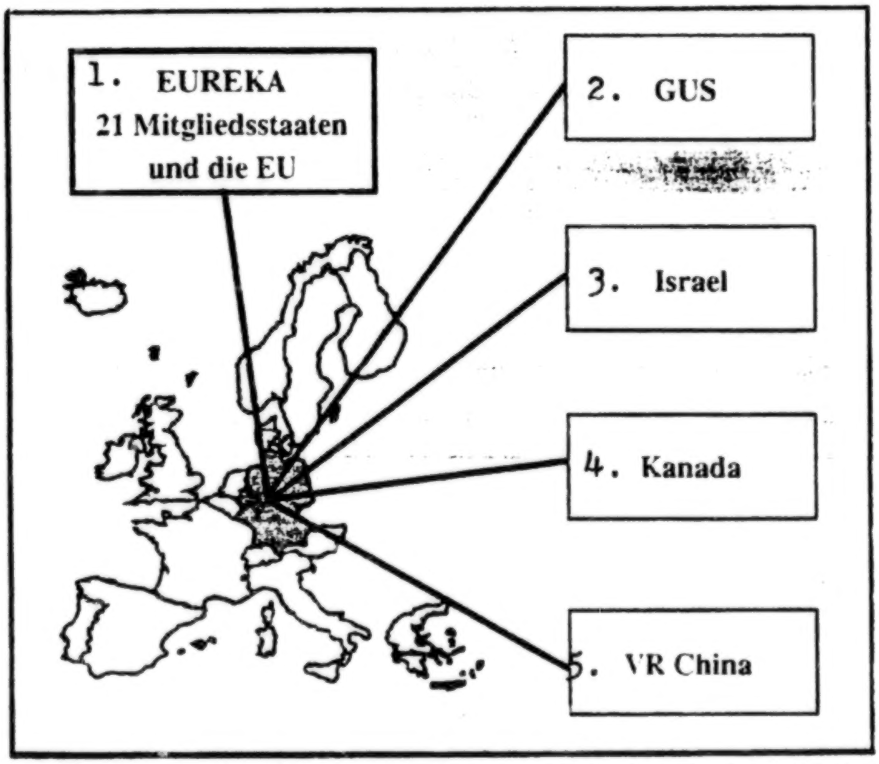

Fig. 6. International cooperation with other countries under the Eureka technology initiative (Source: VDI Technology Center, Duesseldorf)

Key: 1. Eureka: 21 member states and the EG—2. CIS—3. Israel—4. Canada—5. People's Republic of China

4. Current Market Trends, International Competitive Position of the Federal Republic of Germany and Technological and Scientific Lines of Development

4.1 Market Trends

The international market for laser beam sources was on the order of magnitude of about DM1.7 billion in 1992 (Fig. 8). Of this, 38 percent was made up by industrial laser material processing, 30 percent by information and communications technology, 27 percent by laser medical technology and 5 percent by laser metrology. The significance of laser technology for the national economy becomes clear in an analysis of the systems market, in which lasers are key functional components: the cost factor between laser beam source and laser system or laser-equipped end device is around 4 to 5 in material processing, 5 to 6 in laser medical technology, 20 in laser metrology, and 50 to 60 in information and communications technology.

Accordingly, the international market volume for laser systems in 1991, depending on the definition of systems, was between DM30 and 50 billion overall (PROGNOS 1992, [2], and Herziger 1991, [3]).

According to market research, the realistic diffusion potential of laser technology in the area of material processing was about 5700 companies in the Federal Repubic (IFO 1990, [1]). Using average values based on experience, an investment volume of at last DM2 billion and annual sales on the order of magnitude of DM5 billion can be anticipated. The value created by laser use through follow-up products and gains in productivity with new production techniques should be even greater. It should be noted that these estimates are based only on the laser techniques already introduced in the market; innovations would lead to even greater increases in sales.

CO_2 lasers with beam power of significantly more than 10 kW have good market growth chances in welding and surface processing. Solid-state lasers will continue to gain in importance, penetrate into the application area of CO_2 lasers and open up new applications and markets. This will be made possible by moving to higher power levels, by the increased reliability of these lasers and by the systems simplfication caused by optical fibre transmission and more favorable mechanisms for linkage to the equipment.

Diode-pumped solid-state lasers will increasingly find applications in various areas of material processing,

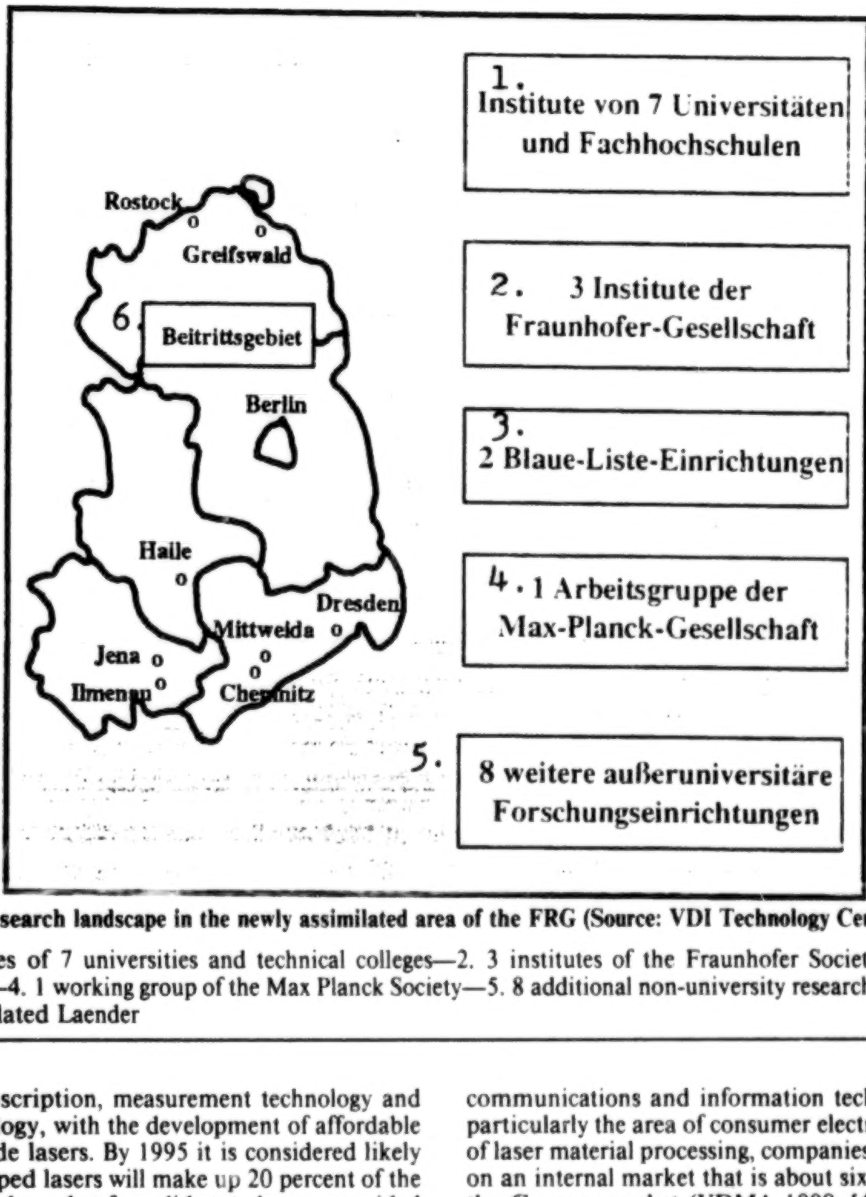

Fig. 7. Laser research landscape in the newly assimilated area of the FRG (Source: VDI Technology Center, Duesseldorf)

Key: 1. Institutes of 7 universities and technical colleges—2. 3 institutes of the Fraunhofer Society—3. 2 Blue List establishments—4. 1 working group of the Max Planck Society—5. 8 additional non-university research establishments—6. Newly assimilated Laender

marking and inscription, measurement technology and medical technology, with the development of affordable high-power diode lasers. By 1995 it is considered likely that diode-pumped lasers will make up 20 percent of the value of the total market for solid-state lasers, provided that it is possible to master the considerable scientific and technical challenges in high-power diode lasers.

Direct use of radiation from high-power diode lasers is already considered to have significant market chances within a few years. Above-average market growth rates are also anticipated in the future for excimer lasers for use in microprocessing.

These new development trends for laser beam sources are balanced by numerous potential applications which have not yet been fully utilized.

4.2 Competitive Position

The competitive position of individual countries is very different in the different market segments of laser technology. Japanese companies dominate the market for communications and information technology, and also particularly the area of consumer electronics. In the area of laser material processing, companies in Japan can rely on an internal market that is about six times larger than the German market (VDMA 1990, [4]). Here Japan is counting on standard products (cutting systems, high quality, large inventories) and is pursuing an aggressive market saturation strategy (currently about 40 percent of the international market).

The large-scale research project AMMTRA (Advanced Material-Processing and Machining Technologies Research Association) is intended to secure the predominance of Japanese industry in the area of beam and surface technologies and of excimer lasers in the long term.

The sphere of the laser industry in the U.S. is in the area of laser medical technology with a large internal market (60 percent of production) and in laser measurement technology and lasers for the research market. The U.S. takes second place behind Japan in communications technology.

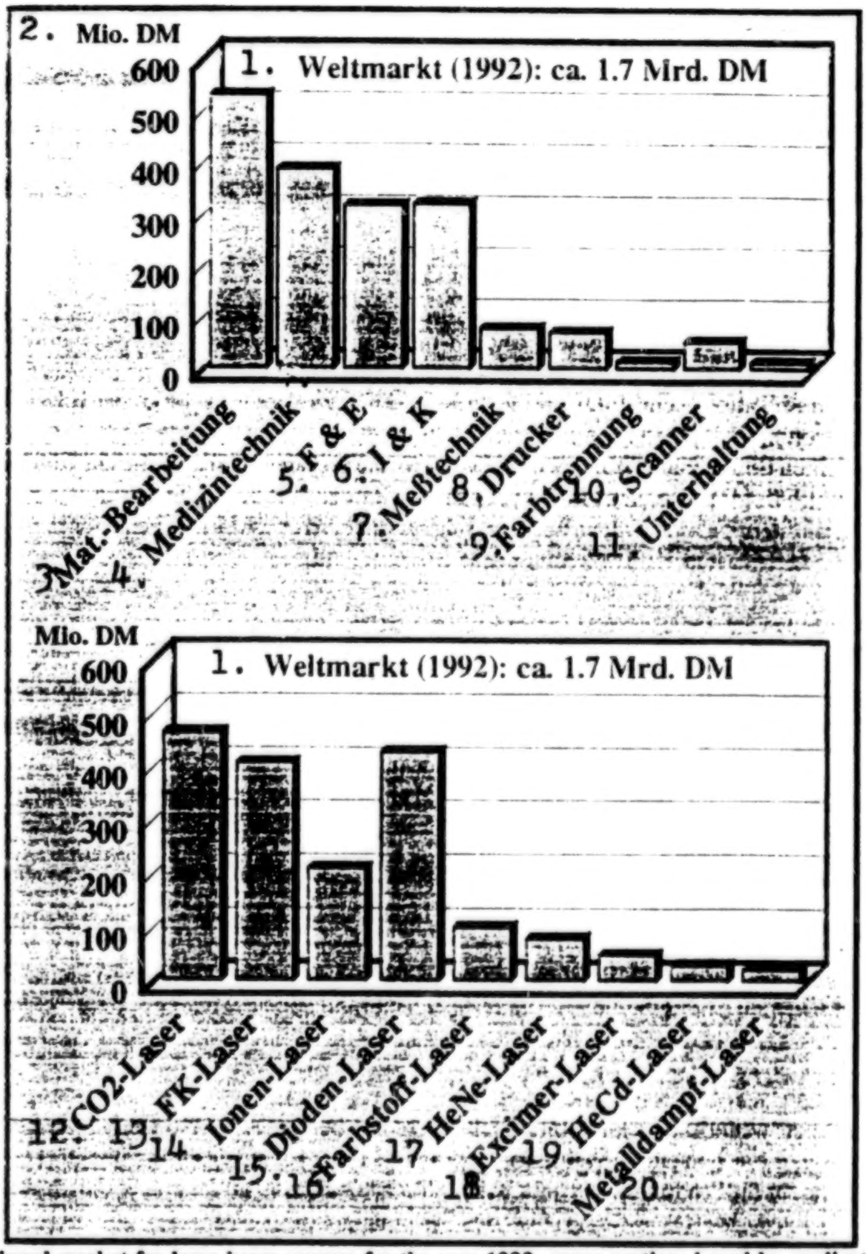

Fig. 8. International market for laser beam sources for the year 1992; upper portion: keyed by application fields; lower portion: keyed by laser types (Source: Laser Focus World, January 1993, data based on exchange rate of $1.0 to DM1.70)

Key: 1. International market (1992): approx. DM1.7 billion—2. Millions of DM—3. Material processing—4. Medical technology—5. R & D—6. Information and communications technology—7. Measurement technology—8. Printers—9. Color separation—10. Scanners—11. Entertainment—12. CO_2 lasers—13. Solid-state lasers—14. Ion lasers—15. Diode lasers—16. Dye lasers—17. HeNe lasers—18. Excimer lasers—19. HeCd lasers—20. Metal vapor lasers

Government sources in the U.S. are currently subsidizing sweeping technology transfer programs with the goal of making the military laser knowhow acquired in the programs of the Department of Defense (DOD) and the Department of Energy (DOE) usable for civilian purposes. For lasers this involves particularly high-power diode lasers and diode-pumped solid-state lasers.

Germany is the technology and market leader for excimer lasers. German laser manufacturers also have a

leading role in the technology of CO_2 laser beam sources of the kW class, as reflected in an international market share of 27 percent. In the area of laser systems for production technology, in contrast to Japan, the situation is defined by a strongly diversified and specialized range of systems.

On the whole, with the exception of the area of diode lasers, Germany offers a good scientific and technical environment, and to some degree a good environment for the anticipated developments on the international laser market. But there is a danger that significant market shares will be taken over by Japanese companies even in the area of industrial material processing, particularly as they offer inexpensive and simple systems. Retreating exclusively to high-priced special solutions could have serious consequences for the laser industry in Germany, analogous to experiences in other technological areas.

4.3 Developmental Directions

In the area of laser beam sources, work is being done worldwide on the further development of existing beam sources and on new laser types for various applications. The scientific and technical lines of development which are emerging (Fig. 9) [not reproduced] are characterized by

- miniaturization and more compact construction;
- greater power and better beam quality;
- opening up of new wavelength ranges;
- improved maneuverability.

The general goal is the complete control of coherent light with respect to all its properties, such as wavelength, polarization, power, intensity, spatial and temporal pulse form and pulse sequence. This goal has only been realized to a limited degree so far.

An important future line of development in the area of laser beam sources is emerging among high-power diode lasers and diode-pumped solid-state lasers. Both in Japan and in the U.S. intensive research is being carried out in this area. Although Germany is lagging behind to a certain degree, access to international developments can certainly still be obtained. The line of development of high-power diode lasers signals a new generation of lasers (semiconductor technology—"all solid state"—replaces tube technology), and likewise a future change of structure in the laser industry.

In the area of applications the laser will penetrate production technology ("factory of the future"), and will also penetrate increasingly into the areas of medicine, biology and chemistry (minimally invasive therapy, laser biodynamics, micromanipulation, beam-induced processes).

In laser applications, two developmental tendencies are central:

- Exploiting the application potential with known laser types
- Opening up new application fields with future lasers

Significant trends for new laser applications are heading in the direction of

- Greater spatial and temporal precision
- Intelligent laser systems, control of the effect by sensory and diagnostic feedback
- Industrial use of phenomena previously used predominantly in basic research (e.g., non-linear optics, short-time spectroscopy, short-wave lasers and X-ray lasers).

Important application fields are to be found, for example, in the areas of precision separation and removal of materials with laser photons (Fig. 10) [not reproduced]. This will make it possible, for example, to galvanize without current and without harming the environment or to construct very delicate, specific three-dimensional structures. Completely new applications can be opened up by the penetration of laser light into molecular and atomic structures (e.g., laser biodynamics, micromanipulation).

Through the application of new laser developments it will be possible, for example, for medical technology in collaboration with endoscopic techniques to minimize the traumatic effect of surgical intervention on the patient ("gentle operations").

5. Role and Goals of Research Policy

It is an essential priority of the economy to carry out future research tasks under its own responsibility, in order to assure its competitiveness. Government support of research and development can thus in principle only function as a subsidiary resource.

Rapid technological progress is among the most important marks of the strength of economic systems based on a market economy. Numerous innovative enterprises, including some in the area of laser production and laser applications, are constantly seeking for improved technological solutions for new products and more efficient production methods to asssure or expand their earning potential.

This process can only be mastered by having responsibility and decision-making vested in the individual companies which can evaluate and satisfy the requirements of consumers specifically on the basis of their experience and knowledge of the market.

Within the context of the tasks of the economy described above, the state can only take an active initiative where significant research gaps become apparent. Here state support is guided by the principle of subsidiarity: only when the companies themselves cannot develop certain technologies of great significance for the whole economy, or cannot develop them quickly enough or with sufficient breadth, does the Federal government see basic prerequisites for state research support in the business economy. It is limited as much as possible to helping business help itself.

The necessary conditions for subsidy are found particularly in the case of a need in basic research, to the extent that the economy does not have sufficient incentive from the point of view of profitability, and in the area of protective research (environment, health, etc.). Subsidization of companies in the business economy starts from the assumption that technologies will be supported which will benefit significant portions of the total national economy, beyond the interests of a single economic sector, or which are necessary to fulfil state protective functions.

Subsidization policy plays a special role for small and mid-sized companies, if their innovative capacity is to be strengthened in comparison to the international competition, e.g., in order to prevent attenuation of the important structures which are necessary for the whole economy.

Laser technology possesses considerable significance for the national economy and plays a key role both in the area of protective research (health, environment, climate, energy) and for increasing technological and industrial capacities based on its influence on almost all areas of technology, the natural sciences and medical technology. Through its broad applicability it can offer a significant contribution to the creation of favorable conditions for a rapid growth in important branches of the economy.

After the initial invention of the laser in the U.S. in 1960, the subject was certainly taken up by individual scientists in the Federal Republic of Germany. However, until well into the 80's the research possibilities were relatively inadequate, and above all not rigorous enough. Thus it was not until 1981 that the first major institute was founded in Garching, the Max-Planck Institute for Quantum Optics, which was predominantly concerned with basic research oriented towards understanding. At this time there were already powerful research capabilities in the laser area in the U.S., for example at the Massachusetts Institute of Technology (MIT) or large international research facilities like the Lawrence Livermore National Laboratory (LLNL). The first major institute for questions of industrial laser applications in Germany was the Fraunhofer Institute for Laser Technology (ILT), founded in Aachen in the fall of 1984. The ILT and the other laser institutes which were added in the second half of the 80's generally only completed their startup phase at the beginning of this decade. Thus it is only now that the essential conditions exist in which this competence and the German knowledge about lasers in basic and applied research, which is acknowledged beyond the borders of this country, can hold its own in international competition, particularly with centers in the U.S.

In comparison with other technologies whose underlying inventions were made in part well before 1960 (biotechnology, microelectronics, superconduction, thin layer technology), laser technology is relatively young (Table 2). Even today the potentional of the laser is only partially known, in spite of the fact that since the end of the last decade there have been remarkable economic breakthroughs in certain areas, such as in cutting and fitting with the CO_2 laser.

Table 2: Chronological Table of the Development of Quantum Optics

Theoretical foundations (1917-1959)	
1917	Introduction of stimulated emissions
1928	Experimental demonstration of stimulated emissions
1950	Experimental demonstration of a distribution inversion
1951	Proposals on amplification by stimulated emission
1954	First NH_3 gas beam maser
1957	First solid-state maser
1958	Proposal on amplification through stimulated emissions in the optical realm
1959	Proposal for creation of gas laser
1959	Proposal for creation of semiconductor laser
Invention of the laser (1960-)	
1960	First solid-state (ruby) laser
1961	First He-Ne laser
1961	Demonstration of nonlinear optical effect, beginning of development of nonlinear optics
1962	First semiconductor (injection) laser
1965	First color center laser
1966	First dye laser
1969	Combination of (injection) lasers with miniaturized optical and electronic components (integrated optics)
1971	First laser with distributed feedback (DFB)

Table 2: Chronological Table of the Development of Quantum Optics (Continued)

Invention of the laser (1960-) (Continued)	
1977	First free-electron laser (FEL)
1984	First soliton laser
1985	First amplified spontaneous emission laser (ASE)
1985	Production and demonstration of "squeezed states"
1987	Production of 6-fs pulses
1989	First noninversion laser

Source: W. Brunner, K. Junge: LASERTECHNIK. EINE EINFUEHRUNG, 3rd, revised ed., Heidelberg: Huethig, 1987, with supplements by the VDI Technology Center, Duesseldorf

In general, because of the historical development of laser technology in the Federal Republic of Germany, there is a large qualitative and quantitative deficiency in basic research, since over the last few years the laser institutes which have been set up were predominantly dedicated to industrial research to serve the German laser industry's need to catch up with others.

This is also confirmed by observing international professional congresses, in which the working areas of laser research are presented, and in which Germany is not represented or underrepresented (e.g., nonlinear optics, high-power diode lasers, process metrology, production of ultrashort pulses). The necessary preconditions for the industrial laser technology of the future must be improved by subsidizing basic scientific research and investigating technological application possibilities.

In protective research, which is a prerequisite to carry out the protective functions initiated by the state, laser technology has a potential which is far from being fully exploited, with which it can become more valuable, for example, in the areas of health, environment, climate and energy.

Foreseeable breakthroughs in the development of beam sources and their applications make it possible that the advantages of the laser, e.g., in laser medicine, in process control and supervision, and including atmospheric research, could be utilized even more thoroughly. In protection research, too, extensive basic investigations are necessary to begin to tap this potential. To this extent, the subsidy plan LASER 2000 should make important contributions to target areas of the Federal government in protective research.

In this connection it is advisable to initiate forward-looking research projects early on which are concerned with the organizational, qualificatory and health-oriented structural possibilities in laser applications. This woud mean a contribution, for example, to the optimal mastery of the technologies of the 21st century. The state is increasingly being challenged in this area: it must cooperate in producing technological rules, norms and even legislation to ensure the least damaging, least injurious technogical and environmental living conditions. In the face of ever-accelerating technological change, it should help to preventatively open up possible effective and quality-enhancing solutions which can be used in many different industries. That is why the subsidy plan LASER 2000 is intended to give important incentives to projects on the evaluation of technological consequences.

With reference to international competition, individual laser-producing companies in Germany have a good position in some areas of industrial innovation. This is particularly true for CO_2 laser beam sources of the kilowatt class and excimer lasers. These partial successes are essentially based on results of basic research from the 70's and 80's.

Now laser beam source technologies and laser systems technologies are faced with new challenges which are the result of scientific and technical revolutions and structural changes. This includes new perspectives which arise from the new generation of technology, including miniaturized high-power diode lasers, diode-pumped solid-state lasers and compacter gas lasers. These are linked with changes in laser use, which are characterized by greater precision and the opening up of new application fields, in particular through the use of laser beam sources of great compactness or of new wavelengths.

The efforts necessary to achieve this are too large-scale for the capacities of individual businesses in laser research and laser technology companies, which are predominantly small and mid-sized. Another reason for this is that, even more than before, future successes in laser technology will require interdisciplinary cooperation between very different areas of technology, such as optics, electrotechnology, cooling and microtechnology, including material and engineering technology. In these cases state support is necessary, if the companies cannot afford research technology developments with particular economic or social significance under their own steam. The subsidy plan LASER 2000 creates the relevant research policy framework for such developments.

To sum up, it can be demonstrated that the state subsidy measures provided necessarily require the following actions in the area of laser research and technology:

- Funding goal-oriented basic and applied research in areas which already have high relevance for industrial application, as well as significance for pure science

- Supporting R&D in research institutes and companies in order to make a contribution and to advance developments in laser technology more rapidly in the intersts of the national economy as a whole
- Targeting funding to technologies whose significants extends beyond individual branches of the laser industry or individual companies, or which are necessary to carry out state protective mandates (environmental and health protection)
- Supporting measures which encourage innovation or diffusion (including technical regulations, norms, qualifications).

The central task of the subsidy plan "LASER 2000 from the point of view of research and technology policy consists of improving the conditions making it possible to develop this key technology through targeted subsidy options and measures to improve the structure.

In laser technology this means, as will be set out in what follows:

- Obtaining an efficient research infrastructure
- Redefining targeted research goals in laser science
- Improving the innovative capacity of businesses, in particular of small and mid-sized companies

5.1 Research Infrastructure

There are efficient, applications-oriented working groups at non-university institutes and technical colleges which have been making a signficant contribution to the current status of laser research and laser tehcnology for some time (Fig. 11).

One of the characteristics of far-reaching change in industrial areas is the drive towards shorter and shorter cycles of innovation. This can only be successfully dealt with in laser technologies if, as was the case earlier, it is possible to achieve goal-directed scientific and technical appications-oriented basic results on the perimeter of industrial R&D. This can be achieved supplementarily with the support of a research and technology policy which supports an efficient research infrastructure oriented towards interdisciplinary cooperation, a policy which will guarantee getting a jump on research for fundaments, applications and industrial utilization.

The LASER 2000 subsidy plan, for example, is oriented toward the support of basic resarch and the support of future-oriented research projects for key technologies, particularly if effects which go beyond one particular branch of the industry are to be anticipated as a result—as is the case to a high degree for laser technology—and thus long-term prospects and options are opened up. The subsidy plan is to take on supportive functions.

5.2 New Orientation of Research Topics

Focal points of the previous activity of laser resesarch institutes and of industrial research was primarily in laser beam sources of "conventional" construction and in basic applications in material processing such as cutting and fitting. Most of the results are now in the utilization phase. The new developmental trends described above should be taken up more intensively.

If Germany's lead in the area of laser resesarch and laser technology is to be maintained and it is to catch up in areas where it lags behind, such as solid-state laser development and new laser applications, the companies must address the following developments:

- A new generation of lasers (development of high-power diode lasers and diode-pumped solid-state lasers; here semiconductor technology is replacing expensive tube technology)
- Miniaturization and more compact construction methods for laser equipment, incl. for material processing
- Greater power, better beam quality and increased ease of use in laser systems
- Industrial utilization of laser operation principles (e.g., nonlinear optics, short-time spectroscopy) previously mostly investigated in basic research
- More intensive utilization of previously developed laser technology applications (e.g. excavation, fitting, surface processing)

These developments require a new initiative from the BMFT in subsidy policy strategy, in order to make better mastery of the technology possible and to open up market opportunities in the field of laser technology and laser applications.

Technology funding must take the most important place, i.e., appropriate thematically organized subsidizing activities are to be provided, taking into account the efficiency of the overall economic structures.

5.3 Improvement in Innovative Capacity

In face of the intensified international competition which is developing in this area, there is already a drive towards innovation which can be met efficiently with improved technological insight on the national and international market. Thus an improvement in the capacity to innovate acquires decisive significance.

Because of the complexity of laser technology, a prerequisite for this improvement is close cooperation in research between industry and the basic research institutes of various disciplines. The funding necessary to achieve this exceeds the budget particularly of small and mid-sized companies. Thus they can generally only participate in the market if the transfer of science and technology is made easier and quicker for them by the cooperation of industrial research with institutes.

In a study commissioned by the BMFT (IFO 1990,[1]), the IFO Institute has basically identified the following barriers to diffusion in the dissemination of laser aplications, particularly for small and mid-sized companies (KMU):

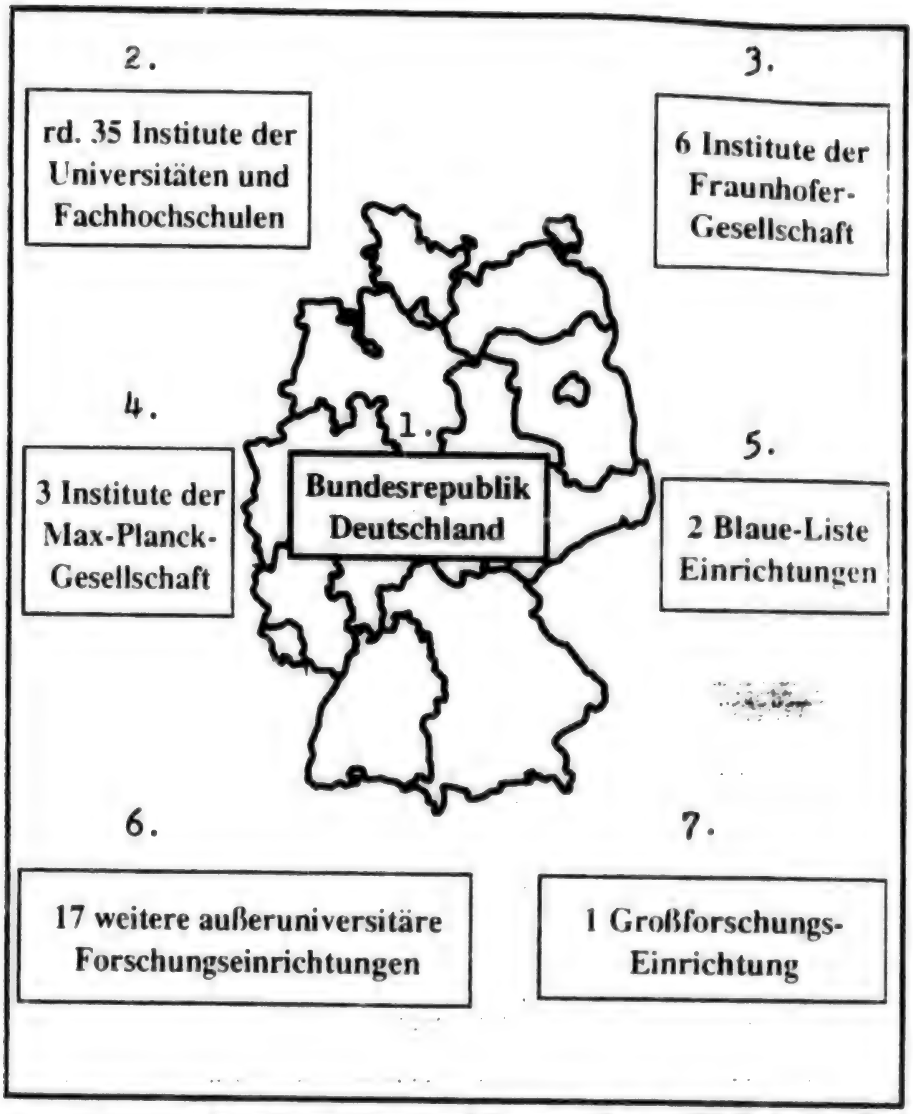

Fig. 11: Laser research landscape in the Federal Republic of Germany (Source: VDI Technology Center, Duesseldorf)

1. Federal Republic of Germany—2. Approximately 35 unviersity and technical college institutes—3. 6 institutes of the Fraunhofer Society—4. 3 institutes of the Max Planck Society—5. 2 Blue List establishments—6. 17 additional non-university research establishments—7. 1 major research establishment

- Technical problems (developmental stage, staging periods, degree of complexity)
- Informational barriers (proprietary processes, application possibilities, lack of qualification)

Here too it is initially the task of business itself to encourage the necessary dissemination. Only in selected fields, particularly in the removal of informational barriers and the first use of laser technology in small and midsized businesses, will the state become active for a limited time, since KMUs in particular cannot close the research gap between the state of the technology and the solution of concrete business problems in this complex and relatively expensive technology on their own to improve their innovative capacity.

This is true both of research and development efforts to create new basic and applied solutions and also of projects which prepare for and carry out innovations.

Taking into account the efficiency of the overall economic structures for disseminating innovation and technology, the subsidizing activities in the LASER 2000 subsidy plan will be set up to support the translation of research results into industrial applications.

The subsidy measures of the BMFT are therefore organized perdominantly in the form of industrial joint projects between science and business even in the field of applications-oriented basic research. In this way synergies will be brought into play in the cooperation between

government-financed research groups and engineers from industry, to the advantage of both groups. In addition, new and interesting questions for basic and preparatory research will arise precisely from the cooperation between science and industry. The supply of qaulified new generations of scientists will increase, and they will make the move to industry and thus the "mind to mind technological transfer" easier.

6. Goal-setting and Target Areas of the Subsidy Plan

The extension of the previous subsidy measures starts from the present scientific and technological position and the developmental trends presented abovel. Thus a strategic initiative is used as a basis for the LASER 2000 subsidy plan, for the following purposes:

- To encourage the opening up of future technology fields in the sense of a long-term forward-looking research and technology policy, and guarantee the foundations and the scientific competence for laser technologies of the next century by the support of preliminary research
- To catalyze an innovative thrust in industry through intensive cooperation of science and business in laser-producing and laser-applying ventures
- To support laser applications extended over a broad range, based on the state of knowledge already attained.

On the basis of numerous discussions with representatives of laser science and the laser industry and based on the considerations listed above, the following goals and targets emerge:

6.1 Strategic Goal of the LASER 2000 Subsidy Plan

Exploring the scientific and technical bases for the laser technologies of the 21st century

Supporting innovative laser technologies to attain and develop international competitiveness of the laser-producing and laser-application industries

Removing informational and technological barriers in laser applications

6.2 Important Future Targets of Laser Research and Laser Technology

—Bases for new generations of lasers

Currently a fundamental technological revolution is taking place internationally. The laser will turn to new and as yet unexploited working principles, particularly towards "all solid-state concepts," higher power density and improved beam quality. The scientific foundation for this next generation must be laid now. Important pilot projects include:

- High-power diode lasers and diode-pumped solid-state lasers
- New physical working principles for high-power gas lasers

Additional new laser beam sources should involve the opening up of the shortest wavelengths (i.e., in the direction of hard UV and soft X-ray radiation). There should also be exploratory definition phases for new lasers, e.g. iodine-oxygen and CO lasers.

—Precision processing with lasers

Future applications will utilize the laser's capacity to be employed with high spatial and temporal resolution in precision operations. Here the further development of laser technology will also make important contributions to nanotechnology, microsystems technology and microelectronics. Important pilot projects are:

- Qualification of laser procedures
- Laser-induced manufacturing processes
- UV-laser photon technology

—Groundwork for opening up new application fields

Utilization of new physical laser principles, such as nonlinear phenomena and photons as precision measurem,ent instruemnts, should open up new application fields for laser technology. In the course of expert discussions the following new application fields, among others, have emerged:

- Laser-optical measurement and testing procedures
- Nonlinear optics
- Laser biodynamics and laser micromanipulation (entering the molecular and atomic realm)

In laser-supported mesaurement and testing procedures the high spatial resolution and even more the very high temporal resolution of laser procedures should be exploited to the physical limits. The pilot project should be:

- Laser-optical measurement and testing procedures for production and environmental measurement technology

In the interaction between light and material, nonlinear effects appear at intensities that only the laser can offer. Nonlinear optics (NLO) has thus far been the object of basic research with relatively few industrial application fields. Numerous NLO effects, such as parametric enhancement, the opening up of new areas of frequency conversion and beam manipulation, should be investigated with regard to their industrial applicability.

In laser biodynamics, for example, it is potentially possible to replace the restriction enzymes by micromanipulation with the laser in genome analysis, at least in part.

—Laser medicine

Laser technology has important innovative potential for future developments both in minimally invasive therapy

("gentle operations") and in microsystems technology. In addition, the laser offers a range of uses for diagnostic purposes in medicine for the benefit of the patient. An important example is the "nondestructive" measurement of blood components. In general, medical laser technology can also make a contribution to cost-cutting in the health-care system.

Target areas for future research in laser medicine should be the deepening of our understanding of the interaction of laser induced processes in biological systems based on the following pilot projects:

- New laser concepts for medical technology (interstitial laser applications, photoablative procedures)
- Optical tomography

Advances in laser medicine demand the interdisciplinary alliance of technologically and medically oriented research. The goal of further development in medical technology is reducing patient stress (gentle operations), improving the safety of intervention and shortening the length of hospital stays and of rehabilitation. The measures are to be determined by the HEALTH 2000 program and, in the case of minimal invasive therapy, by the "MICROSYSTEMS TECHNOLOGY 1994-1999" program, and where necessary jointly carried out.

7. Pilot Projects and Pilot Topics

The four research targets presented in the previous section are subdivided into pilot projects, which are oriented towards industrial bases for technology fields with midrange or long-term importance, and pilot topics, which are to create important scientific foundations for new technological generations and physical operating principles (Fig. 12). In organization of the projects, interdisciplary approaches are to be combined synergistically. In the implementation stage of the subsidy plan, the concrete formation of the pilot projects and project topics will be adapted to the actual state of development in science and technology. Room for later developments will be made by prioritization. This is particularly true of the target area "Foundations for Opening Up New Application Fields."

The topic areas listed below are based on an intensive dialogue with representatives of science and business. They are based on the evaluation of numerous memoranda and studies. There are areas which promise high innovative potential and for which there is a particular need for research and development. The main emphasis of the subsidy plan is high-power lasers and their applications. The precise assignment of goals, tasks and priorities is to be made more concrete by discussions with experts and announcements closer to the time.

7.1 Foundations for New Generation of Lasers

Pilot Project: High-power Diode Lasers and Diode-Pumped Solid-State Lasers

A new technological generation together with a significant advance in quality in the production of laser beams is being brought about by the transition from tube technology (gas lasers) to semiconductor technology (diode lasers) (Fig. 13) [not reproduced]. On the basis of new "all solid-state" systems gas lasers, dye lasers and conventional solid-state lasers in the power range up to about 5 kW can be replaced in the next few decades by high-power diode lasers and diode-pumped solid-state lasers, at least to some degree. A prerequisite for this is intensive and specific basic research to explore new physical and methodological approaches.

The principle of producing coherent light with semiconductor components, the diode or semiconductor laser, has been known to science since 1962. Numerous applications in spectroscopy (toxin analysis), met.ology (interferometry) and information technology (optic fiber transmission, compact discs) are based on this "mini-laser" with dimensions of a few tenths of a millimeter, which is activated directly by electricity and achieves efficiency of up to 50 percent. Broader applications for semiconductor lasers already exist in optical information technology. In these applications the issue is high modulability and spectral narrow-band effects at relatively low laser power (photonics).

In contrast, the new demands on high-power diode lasers are to produce high power density together with high beam quality and high electro-optical efficiency.

In comparison with traditional lasers, high-power diode lasers or dioe-pumped solid-stsate lasers (Fig. 14) [not reproduced] are distinguished primarily by:

- higher efficiency (factor of 4-10), i.e., production of "cheaper photons;"
- better beam quality (factor of 2-5);
- longer life (factor of 10-1,000);
- more compact construction (factor of 2-10);
- light transmission via optic fibers;
- use of low electrical voltages

This technoloogical advance has far-reaching consequences: advantages listed above lead to higher reliability, lower costs and qualitatively better results during use, e.g., in material processing, the most important application area of high-power lasers. As well as the substitution of conventional lasers, completely new application fields for lasers can be opened up with high-power diode lasers, such as:

- process anaylsis;
- laser-induced chemical processes;
- color generation for TV's and large screen displays

Research projects in the following areas should be given priority:

- semiconductor technology (material and layering systems, structural variants of various emitter systems);
- Beam guidance and beam formation (microoptical fiber systems, holographic optical elements, production of high-energy radiation fields);
- adjustment mechanisms (heat regulation, dissipation mechanisms);
- possible uses of high-power diode lasers

Fig. 12: Target Areas, Pilot Projects and Pilot Topics of the LASER 2000 Subsidy Plan Target Areas

Key: 1. Foundations for new generation of lasers—2. High-power diode lasers and diode-pumped solid-state lasers—3. New physical operating principles for high-power gas lasers—4. Expansion of wavelength domain and mastery of relevant laser properties—5. Foundations for opening up new application fields—6. Laser optics measurement and testing procedures for production and environmental technology—7. Nonlinear optics—8. Laser biodynamics—9. Precision processing with lasers—10. Qualification for laser procedures—11. Laser-induced manufacturing processes—12. UV laser photon technology—13. Foundations for laser-supported production strategies and new systems concepts—14. Laser medicine—15. New laser concepts for medical technology—16. Optical tomography—17. Transmission systems—18. Dosimetry in laser therapy—19. Medical laser analysis and laser diagnostics

Pilot Project: New Physical Operating Principles in High-Power Gas Lasers

It is unlikely that semiconductor technology will be able to establish itself in the power range above approximately 5 kW, so that under current circumstances there will be no alternative to gas lasers in the highest power range even in the long run. The next generation of gas lasers will work on new physical principles with the goal of effecting an extreme reduction in size. Such a technological advance requires considerable basic research in the area of new trigger mechanisms and resonator concepts in order to achieve the requisite high specific power densities. A vision for the future is the running of multikilowatt lasers on a robot arm.

Pilot Topic: Expansion of Wavelength Domain and Mastery of Relevant Laser Properties

At present essentially only five wavelengths are used in industrial laser applications. The generation of new wavelengths is necessary to open up new application fields and to optimize laser-supported procedures and processes. In principle, various approaches to this problem are thinkable, e.g., the use of new laser-active media or frequency conversion with nonlinear optical methods, i.e., new laser types linked with new operating principles. Possible approaches could use iodine-oxygen lasers, CO lasers, X-ray lasers (e.g. by production of inversion conditions in laser-induced plasmas) and particularly new solid-state lasers.

With availability of diode lasers as pumped light sources and of new kinds of laser crystals, such things as safe lasers, tunable lasers, and up-conversion systems can be produced. By using other laser properties, such as beam quality, modulability, pulse formation and sound reduction, new interactions between radiation and material can be achieved with applications in laser biodynamics, laser medicine and laser analysis.

On this basis the solutions to problems in wide application fields such as laser medicine, laser precision processing, laser-optical measurement and testing procedures and laser chemistry (laser-induced chemical change) are attainable.

7.2 Precision Processing with Lasers

Laser photons, as massless, non-contact tools, basically fulfill the requirements for controlling processing very precisely and without inertia (Fig. 15) [not reproduced]. The concept of precision includes the precision of the installation and regulation of all laser processing parameters as well as the precision of the results of processing, e.g., geometry, shape, material and product properties. In comparison with conventional material processing systems, it seems that advances in quality can be achieved if the qualities which are scientifically possible can be exploited up to the physical limits. Therefore, in the required research projects comparative studies comparing lasers with other processing technologies may also be necessary in certain cases, e.g., in plasma, water jet, ion beam or electron beam technology.

Pilot Project: Quality Control for Laser Procedures

In comparison with conventional processing technologies, greater energy densities of higher orders of magnitude are used in lasers, with path energies reduced to the same degree. In particular, the resulting increase in cooling speeds leads to metallurgical modifications which have been only inadequately known, changes in the crystallization and conversion behaviors in the processed materials, and to mechanical and technological properties conditioned by these modifications which have not yet been described. These need to be better understood and controlled; they can only be understood inadequately with current testing procedures and types of probes. All laser processing procedures, when measured by the current high standards of quality and testing, are far from having the necessary quality control and confirmation when compared to conventional procedures. These barriers to introducing the technology have consequences particularly for areas where security is a consideration, such as steelworking, pressurized container construction and shipbuilding.

Priority should be given to research projects in the following areas:

- investigations of short-time laser metallurgy and heat treatment;
- characterization of material behavior, including testing methodology, while observing evaluative criteria (norms and standards);
- systemic aspects of short-time laser procedures;
- characterization procedures for laser radiation (measuring methods, effect of beam quality on the process).

Pilot Project: Laser-Induced Manufacturing Processes

Ablation With Laser Photons

Wear, abrasion and corrosion can be significantly reduced by surface treatment and particularly by layering of materials. Traditional galvanization processes are very harmful to the environment; the quality and homogeneity of layering achieved is only partially satisfactory. In contrast, ablation procedures with laser photons have significant advantages in comparison with conventional processes, such as

- applicability to non-metals, e.g., plastics, ceramics;
- selective and local ablation on selected, necessary zones of components;
- achievement of higher layering quality;
- possibility of producing active and multifunctional surfaces with new physical properties (electrical, magnetic, optical, chemical);
- potential for high ablation rates (high-rate laser layering).

These are also linked with reduced damage to the environment and improved protection of resources.

Necessary research projects should focus on:

- basic resesarch on laser particle deposition (LPD);
- process investigations on high-rate laser layering;

- new layering systems and investigation of their properties;
- new optic laser measuring procedures to characterize and measure layers.

Ablation With Laser Photons (Laser-Supported Ablation)

Along with well-established electron and ion beam technologies, laser photons make it possible to achieve ablation of materials permitting shaping and structuring of three-dimensional components in many different ways. Materials which previously either could not be processed at all or only with difficulty or with damage to the environment can be treated with laser beams of high energy density and modulability. This is true of components made from very different materials for use in microtechnology (including nanotechnology) and for macrotechnological components with complex forms.

Essential research projects with a focus on laser light in the visible and infrared wavelength range are:

- basic research on ablation processes with various laser parameters and materials;
- application of laser ablation to new technical processes and products;
- investigations comparing lasers with electron or ion beams.

Pilot Project: UV Laser Photon Technology

In production technology, for example, UV laser photon technology can play a key role in processes which cannot be achieved in any other way. The specific advantages of laser photon technology lie in the high spatial and temporal precision with which UV photons can interact with a wide range of materials (Fig. 16) [not reproduced]. These interactive processes have not yet been sufficiently investigated, among other things with regard to future industrial application fields.

The application potential lies particularly in

- high-rate microbores;
- micomarking;
- microstructuring and surface modification;
- manufacture of layers and layer systems;
- physical and chemical transformations;
- surface treatment.

There are also important areas of application in environmental metrology and in laser medicine.

Pilot Topic: Fundamentals of Laser-Supported Production Strategies and New Systems Concepts

In itself the laser is not an adequate tool; for instance, a highly precise tooling machine can only be created by combining lasers with peripheral equipment and integrating systems technology. Increased demands for precision and speed as competitive factors in production technology require systematic basic research in particular in the following areas:

- laser-supported procedures for "rapid prototyping;"
- combined procedures to improve procedural stability and affordability;
- systematic analysis of laser-supported procedural chains;
- sensor-supported processing for increased precision;
- adaptronic laser technology;
- transmission via optic fibers.

7.3 Groundwork for Opening Up New Application Fields

Pilot Project: Laser-Optical Measurement and Testing Procedures for Production and Environmental Measurement Technology

With the use of photons as precision measurement instruments, new measurement and testing procedures are to be explored and used to replace antiquated mechanical or electrical measurement procedures in production measurement technology, analysis and environmental measurement technology. This will make it possible to attain higher product quality, an increasingly important facet of international competitiveness.

Guaranteed product quality requires adequate measurement and testing procedures for on-line manufacturing and process control and regulation and total quality control. In the future, laser-optical quality testing will be a key to achieving zero-error production.

Conventional measurement and testing procedures are often no longer adequate to meet today's extremely high standards in production and environmental measurement technology. In contrast, laser-supported procedures are superior to conventional procedures because of their precision, speed, flexibility and above all because of the contact-free operation. The precision of laser-optical measurement techniques consists of their extreme resolution in space and time (Figs. 17 and 18) [not reproduced].

Topic areas for future research are:

- laser-optical quality testing;
- laser-supported ultra-precision metrology (e.g., microstructural measurement);
- laser-optical procedures to reach previously unattainable units of measurement and for multi-component measurement systems;
- laser-optical procedures for process control and regulation;
- process analysis and monitoring using laser-optical methods.

Pilot Topic: Nonlinear Optics

Nonlinear optics (NLO) is a crossover technology with broad applicability for many areas of laser technology, e.g., to access new wavelength ranges and compact laser beam sources. The significance of non-linear optical procedures and components will therefore greatly increase in the future, while the shape of many application possibilities is only now emerging.

NLO has already been broadly investigated in the context of basic research and put into practice to some degree. The goal of subsidy measures is to investigate partial aspects of NLO with regards to their technical feasibility, particularly to extend the power range to industrial relevant magnitudes.

Here the economic significnce lies not so much in the market for the various nonlinear optical components, but rather in the manifold solutions for problems and systems made possible by NLO and in the systems market.

The focus of subsidization should be:

- Frequency conversion: Methods and components to access new wavelengths from the ultraviolet (UV) to the infrared region of the spectrum (e.g. parametric enhancement, frequency multiplication and mixing (up-conversion)
- Beam formation and beam manipulation: Production of ultrashort light impulses, modular coupling, modulation, phase conjugation, coherent coupling of laser radiation
- Nonlinear optical procedures and components for mrecision measurement and testing technologies: Surface and boundary analysis (surface harmonics), process analysis, optical signal preprocessing for precision metrology

Pilot Topic: Laser Biodynamics

The relatively new concept "laser biodynamics" refers to the use of lasers in biological systems particularly on the level of cells and biological macromolecules such as DNA. Light, e.g., as an energy carrier, has elementary significance for processes in biology. The goal of laser biodynamics is to produce a combination of laser technology and biological systems in order to gain a better understanding especially of the dynamcis of biological processes and make them technologically useful. This requires the use particularly of the extreme spatial and temporal resolution and manipulability of laser light.

Some topics of future research would include:

- laser microprocessing of biological cells and biomolecules with the help of optic tweezers;
- DNA analysis by isolation of DNA sequence framents with the help of UV laser photons;
- Understanding of the molecular dynamics and kinetics of biological processes and systems with the help of short-time laser spectroscopy;
- identification of biomolecules in clinical diagnostics, in environmental and nutritional analysis (optic biosensors);
- illumination of the process of photosynthesis.

7.4 Laser Medicine

Medicine is undergoing a revolutionary change at the moment: many of the long-established surgical procedures are being replaced by new techniques of "minimally invasive therapy." These new techniques are characterized by minimization of surgical intrusion. For this purpose laser technology procedures are combined with endoscopic techniques. For example, the "optical scalpel" has come about in this way, and can be used to operate very precisely and with small amounts of blood even internally (tissue cutting and coagulation). New applications of laser medical technology can be opened up beyond this therapeutic use of the laser in the areas of diagnosis, analysis, tumor diagnosis and therapy, and also optical tomography ("optical X-ray").

The goal of these research projects is to reduce patient stress ("gentle operations"), to increase the safety of intervention and also to shorten the length of hospital stays and of rehabilitation.

Pilot Project: New Laser Concepts for Medical Technology

Rising demands for quality in therapeutic care and greater therapeutic safety for both doctor and patient increasingly require intelligent therapy systems. The combination of laser technology and sensors and modern laser technology permits on-line diagnosis and analysis.

In the following project suggestions along the lines of preliminary research, the emphasis is on interdisciplinary cooperation between various technologies and research fields (systems integration). In addition, new application fields for minimally invasive therapy (MIT) need to be identified and available MIT procedures need to be optimized.

Interstitial Laser Applications

The objective of interstitial laser application is to incorporate beam energy into tumorous tissue in a controlled way while protecting the patient and to destroy the tumor in this way. Here the beam energy can be used directly. The tumor is necroticized by the applied heat.

Another possibility is that of sensitizing the tumorous tissue to laser radiation through the introduction of certain reagents, so that phototoxic reactions take place during irradiation and destroy the tumor (Fig. 19) [not reproduced].

Research projects should be directed towards:

- Determination of laser-tissue effects (optical tissue properties, optimized sensitizer (dye) and carrier systems for improved tumor selectivity), optimization of laser beam source;
- delivery and catheter systems, laser-supported diagnosis and image-producing procedures;
- therapy planning, process control (suitable diosimetry), regulation of the therapy system.

Photoablative Procedures

Here the targets of research are new systems adapted to medical requirements; in the near infrared spectrum new wave lengths need to be made accessible for photoablative procedures so as to work for a better adaptation to

various tissue types. Here goals such as more compact, sturdier and less expensive systems should be taken into account.

The requisite research projects are:

- adaptation and optimization of laser beam sources according to medical requirements;
- short-pulse and cyclical laser beam sources and assoiated delive.y systems for optimization of existing and new forms of therapy;
- diagnostic sensor procedures for on-line detection of tissue changes, new measurement techniques for rapid and exact determination of ablation;
- opening up new application fields for minimally invasive therapy.

Pilot Project: Optical Tomography

Optical tomography (replacing X-rays with laser beams) operates with pulsed laser radiation in the visible and infrared domain. In the future it could replace certain applications of X-ray technology which are particularly risky for the patient because of the shortwave radiation. A prerequisite is a comprehensive investigation of the technological and scientific foundations, such as investigations of tissue-optimized optical tomography procedures and testing of their use in vitro. In addition, optical laser procedures such as fluoroscopy for early identification of tumors or for throwing light on metabolic disturbances should be investigated.

Research projects should be undertaken in the following areas:

- basic research on optical tomography and tumor diagnosis;
- optical laser diagnostic procedures (fluoroscopy);
- research projects on sensors and metrology for the above procedures;
- system configurations (modelling, simulation, metrological structure, image processing).

Pilot Topic: Transmission Systems

In endoscopic operating methods the laser, as a piece of medical equipment, is imbedded in a complex system made up of beam guiding, beam-forming and beam-handling systems, to transport the laser radiation into the interior of the body. Because of the availability of new wavelengths, particularly in the near infrared, new optic fiber technologies for endoscopic procedures must be investiaged, bearing in mind the necessary safety features.

Topic areas for future research projects are:

- new lightwave conductors;
- beam formation, indication-specific applicators, integration of sensors, linkage with medical equipment such as ultrasound and nuclear magnetic resonance (systems integration)

Pilot Topic: Dosimetry in Laser Therapy

Dosimetry is on a high technological level in current radiation therapies (e.g., X-ray medicine). In laser therapies it is still at the stage of basic research. Thus the goal is investigation of dosage effects in laser therapy and the investigation of relevant dosimetric procedures for objective evaluation of the course of treatment, as well as the necessary effect on laser beam parameters to optimize therapy.

Research projects should be directed toward:

- foundations of the effective mechanisms of laser radiation in biological tissue (biophysical properties of tissues and dynamic change in them when irradiated);
- procedures for on-line regulation of beam sources;
- research projects on dosimeters and systems integration.

Pilot Topic: Medical Laser Analysis and Liaser Diagnostics

The laser's potential for medical laboratory technology has only been inadequately explored so far. The spectrum of possible diagnostic and analytical laser applications ranges from interferometrical, holographic procedures (e.g., growth processes, three-dimensional microscopy) to fluorescence-inducing procedures (e.g., cell sorting, receptor diagnostics) to ultrashort-time diagnostics (time-released laser fluorescence diagnostics for metabolic monitoring). With the availability and use of new medical laser-analytical methods and laser diagnosis procedures, time-consuming conventional analysis and diagnosis procedures can be replaced and the precision of measurement can be significantly increased.

Research projects should be undertaken in the following areas:

- tissue differentiation for diagnosis and therapy;
- monitoring of metabolic products;
- work on photodynamic diagnosis;
- development of laser-specific methods of measurement and analysis for the laboratory.

8. Innovative Initial Applications of Laser Technology in Small and Mid-sized Companies

8.1 Simplified and Limited Subsidy Procedures for Small and Mid-sized Companies (KMU-Oriented Measure)

In principle, small and mid-sized businessses (KMU) can and should also participate in the pilot projects and pilot topics described in the previous section. This is a goal of research policy, particularly because KMUs play an indispensible role in the innovative process in the German economy, including the area of lasers.

However, the participation of KMUs in joint ventures which are pre-competitive and designed to cover several years makes heavy demands on these businesses and usually cannot be reconciled with their interests and the

attitude towards innovation, which is oriented towards short-term utilization of R&E results. This is the same conclusion reached by the IFO study, which also demonstrates that because of the great application potential of the laser, laser and laser system manufacturers cannot meet the demand of the market in its full breadth, either economically or in manpower. This is the starting-point for the following measure.

Within the context of previous laser research and laser technology subsidies, the first task was to investigate the various application possibilities of industrial lasers (CO_2, solid-state, excimer lasers) based on their operating principles. Now the basic knowledge of normal laser applications (cutting, welding, surface processing) are available in principle. But there are still numerous obstacles standing in the way of their practical and widespread introduction, particularly in the user industry, which is predominantly oriented towards the middle range. One of the causes is the fact that in spite of the existence of knowledge about the basic operating principles, in any particular application highly innovative and in part also costly and time-consuming R&E projects may have to be undertaken to introduce the laser into the individual factory. This is demonstrated by the degree of dissemination in laser applications, which is still low at present; for example, it is only about 30 percent even in cutting.

In order to remove the obstacles to innovation which still exist (particularly technical problems and information barriers), small and mid-sized businesses are to be stimulated to innovative initial introduction of laser technology by a simplified subsidy procedure which involves cooperation between companies and suppliers, particularly research institutes. An important requirement for carrying out this measure is the availability of the research infrastructure created in the first subsidy phase and the operating principles worked out in the joint projects on laser applications. This measure is to be limited with respect to extent of funding and length of time (see paragraphs 11 and 12).

The stimulation of broadly innovative application of laser technology to be achieved by this KMU-oriented measure is simultaneously complementary to the general subsidy programs of the BMFT which are oriented exclusively towards KMUs, such as

- R&E loans for innovative advances (Credit Institution for Reconstruction/BMFT R&D loan Program for Small Businesses for Application of New Technologies);
- subsidization of cooperative research (BMFT Program for the Midlevel Economy).

8.2. Evaluation and Advising Centers

The infrastructure required for carrying out the KMU-oriented subsidy measure, e.g., at university and non-university research institutes is only prepared in a limited way to initiate the relevant agreements. What is missing specifically is the necessary personnel and equipment technology for introductory and technological initial advising. The "Evaluation and Advising Centers" measure should create the necessary conditions in selected locations allocated so as to be regionally balanced. In the process, centers with different professional and structural orientations (such as trades) are to be set up. These centers are intended to be obligated to cooperate closely with private consulting firms in order to avoid competitive distortions.

9. International Cooperation

International cooperation and division of labor is indispensible for the further devlopemnt of laser technology, particularly given the background of the internal EU market from 1993. Within the framework of the previous support of the Eurolaser project of the Eureka technology initiative important conditions for international networking of the Western European laser research landscape were created. Certain topics cannot be approached efficiently without international cooperation; for instance, this is true of R&D projects in the preparatory phase of norms and standards.

That is why the LASER 2000 subsidy plan also supports international cooperation for suitable selected topics. A decision should be made on a case-by-case basis about the appropriate mechanism (EU, Eureka, bilateral cooperation). In future, cooperation with Central and Eastern European countries (MOEL, and particularly the CIS) should be built up and expanded to supplement the previous intensive cooperation with Western Europe.

10. Ancillary Measures (Transfer of Information and Results, Evaluation of Consequences of Technology)

The funding of R&D projects can be significantly enhanced by the support of selected ancillary measures accompanying research. For example, the transfer of information and results of the funded projects can be increased by distributing the results, in addition to the usual final reports, in the form of presentations, workshops, brochures and the like; the standardization which accompanies development is also an important measure to suport widely effective dissemination of laser technology (Fig. 20). The appropriate associations should receive special attention for their multiplicative effect, e.g., through making relevant materials available to them.

Important measures to strengthen the technology-oriented subsidization activities include:

- evaluations of consequences of technology;
- transfer of knowledge and information;
- support of developmental standardization.

The researches on evaluation of the consequences of technology already undertaken in the first subsidy phase (target area: further development, laser safety) should be carried further. The future target area should be the systemic aspect of laser technology with reference to ecology and ergonomics (e.g., "Strategies for Industrial Production in the 21st Century" or "Systemic Structural Analysis on the Development of Human-Oriented Ergonomic Concepts."

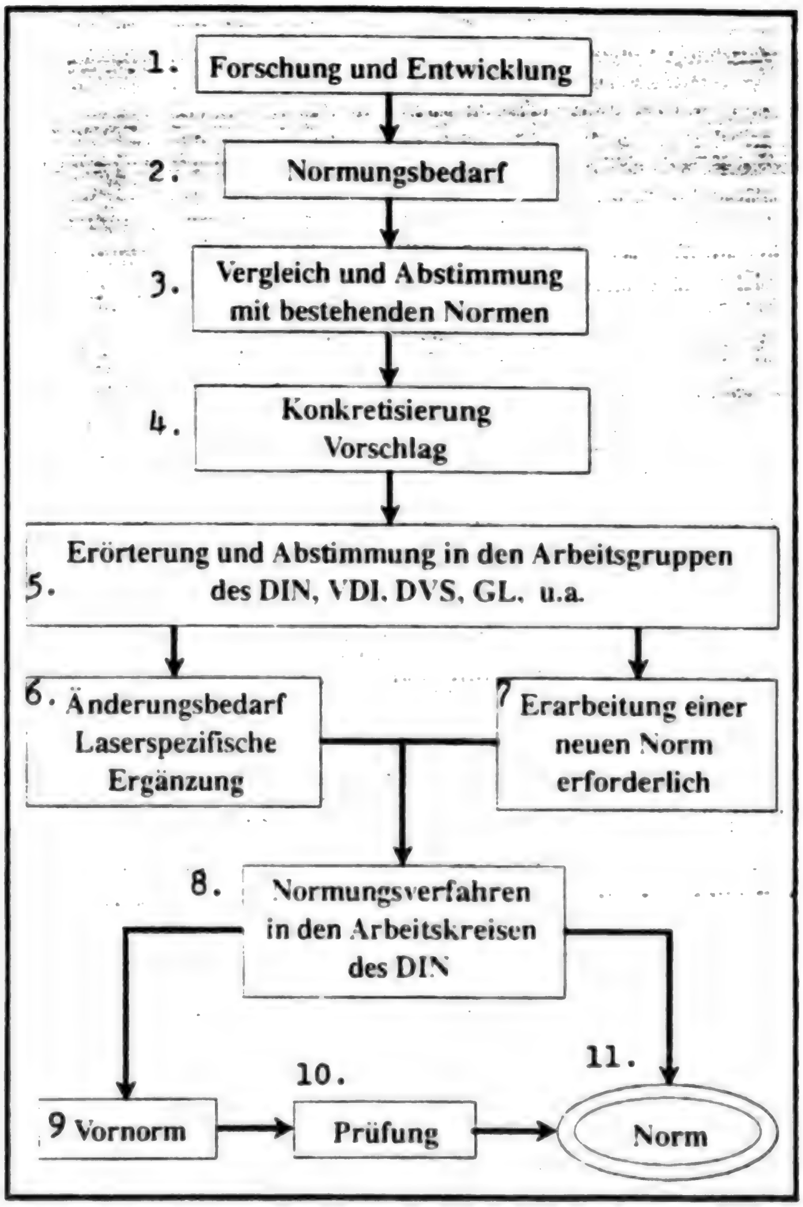

Fig. 20: Initial stages of developmental standardization (source: Bremer Institute for Applied Beam Technology, German Institute for Standardization e.V. Pforzheim office, VDI Technology Center, Duesseldorf)

Key: 1. Research and development—2. Need for standardization—3. Comparison and adjustment to existing standards—4. Concrete proposal—5. Discussion and voting in the working groups of the DIN [German Industrial Standards], VDI [Society of German Engineers], DVS, GL, etc.—6. Need for alteration; laser-specific supplement—7. Need to develop a new standard—8. Standardization procedure in the working groups of the DIN—9. Preliminary standard—10. Testing—11. Standard

11. Timetable and Financial Planning

11.1 Timetable

A five-year period from 1993-1997 is envisaged for implementing the program. This period is mainly determined by the nature of joint research projects, for which at least four years have to be built into the planning, including the preparatory phase.

Program evaluation is to take place in two stages: accompanying the program from 1994 and to some extent retrospectively from 1996.

11.2 Financial Planning (Status: as of January 1994)

Budgetary planning and mid-range financial planning anticipated the following funding for subsidization of laser research and laser technology through the LASER 2000 subsidy plan within the period 1993-1997 (in millions of DM):

- 1993 (actual) 2.3;
- 1994 (projected) 66.0;
- 1995 (projected) 69.0;
- 1996 (projected) 69.0;
- 1997 (projected) 69.0

This level of total funding, about DM275 million, will permit technology-oriented R&D projects, KMU-oriented measures, including evaluation and advisory centers, and ancillary measures to be implemented, in order to bring laser technology in Germany to a position of leadership in the 21st century.

For implementing the KMU-oriented measure increased funding to a minimum of DM5 million annually is built into the plan beginning with 1995 (approximately 25 projects a year). This gives a funding distribution (in millions of DM) of:

	1993	1994	1995	1996	1997	total
Target areas, including ancillary measures and evaluation and advisory centers	2.3	64.0	64.0	64.0	64.0	258.3
Initial application in KMUs	—	2.0	5.0	5.0	5.0	17.0
Total	2.3	66.0	69.0	69.0	69.0	275.3

12. Subsidizing Instruments, Subsidy Requirements, Sequence

Subsidization Instruments

Further development of laser technology will continue to require interdisciplinary cooperation and synergy in the future. Thus the main instruments for subsidization of technology should be "industrial joint research" and for basic research projects they should be "research associations. (Fig. 21).

The KMU-oriented measure (contractual R&D) will be implemented within the framework of individual projects favoring KMUs (annual sales up to DM200 million). Details will be regulated by a separate set of subsidy guidelines. In subsidizing evaluation and advisory centers, a suitable individual contribution will be expected. Details on both mesaures will be communicated in an announcement or a set of guidelines which will be announced.

Subsidy Requirements

The subsidy quotas for project subsidization follow Article 92 EEC Treaty in connection with the "Community Framework for State R&D Assistance" of the EU Commission and the administrative practice of the EU Commission. This means:

For industrial joint research, subsidy quotas

- up to 50 percent for the R&D stage "basic industrial research;"
- up to 25 percent for the R&D stage "applied research."

The subsidy level can lie between 25 and 50 percent, depending on what the proportion of applied research or of industrial basic resesearch is. College institute and comparable institutes whcih deduct on the basis of expenditures can be subsidized up to 100 percent in industrial joint research.

However, the total percentage of state subsidization may not exceed 50 percent (25 percent where applicable) of total costs.

For funding activities in the new Federal Laender a bonus of 10 percent can be allowed until further notice (initially for grants up to 28/2/1996). Companies which do not employ more than 250 workers, either achieve annuual sales of no more than 20 million ECUs or a balance of no more than 10 million ECUs and own no more than 25 percent of a large company can be allowed an additional subsidy bonus of 10 percentage points (see Community Framework for State Assistance for Small and Mid-sized Businesses). Accumulation of bonuses for R&D in the new Federz' Laender is possible up to a total of 15 percentage points.

For basic research projects at colleges and nonuniversity institutes, a subsidy quota of 100 percent is allowed in principle in the context of "research associations."

The principles of project subsidization of the BMFT apply, namely the General and Special Subsidiary Regulations for Applications for Project Subsidization on the Basis of Expenditures (ANBest-P-BMFT) and the subsidiary regulations for grants on a cost basis for members of the business community for research and development projects (NKFT 88).

For the simplified subsidy procedure (KMU-oriented measure) subsidy quotas between 25 and 40 percent are provided for, depending on the size of the business and the company location (NBL), with a grant limit of DM0.2 million. Details are regulated by a set of subsidy guidelines.

Process

Program implementation is done through the project representative of the BMFT:

VDI Technology Center Physical Technologies Graf-Recke-STr. 84 40239 Duesseldorf Tel.: (0211) 6214 401; Fax: (0211) 6214 484

Fig. 21: Types of joint research with subsidy quotas in percent and definition and assignment of the relevant R&D stages, ignoring any addition subsidy preferences for small and mid-sized businesses and the new Federal Laender (Source: VDI Technology Center, Duesseldorf)

Key: 1. Types of joint research—2. Up to 50 percent—3. Industrial joint research; industrial basic research (up to 50 percent), applied research (up to 25 percent)—4. Industry—5. Cooperation—6. Colleges and research institutes—7. Research association; basic research (100 percent)—8. Colleges and research institutes—9. Definition of the relevant R&D stages according to Article 92 of the EEC Treaty: Basic research is understood by the Commission to mean an expansion of general scientific and technological knowledge which is not oriented towards industrial or commercial goals. Industrial basic research is defined as independent theoretical or experimental work whose objective is to gain new or better understanding of the laws of science and technology, including their application to an industrial sector or the activities of a certain company. The Commission conceives of applied research as research and experiments on the basis of industrial basic research with the purpose of gaining new knowledge to make it easier to achieve specific practical goals such as the creation of new products, production techniques or services. Normally it can be said that it ends with the creation of a prototype. (Source: Community Framework for State R&D Assistance: Gazette of the European Community Nr. C83/2 of 11/4/1986).

How Is the Application Made?

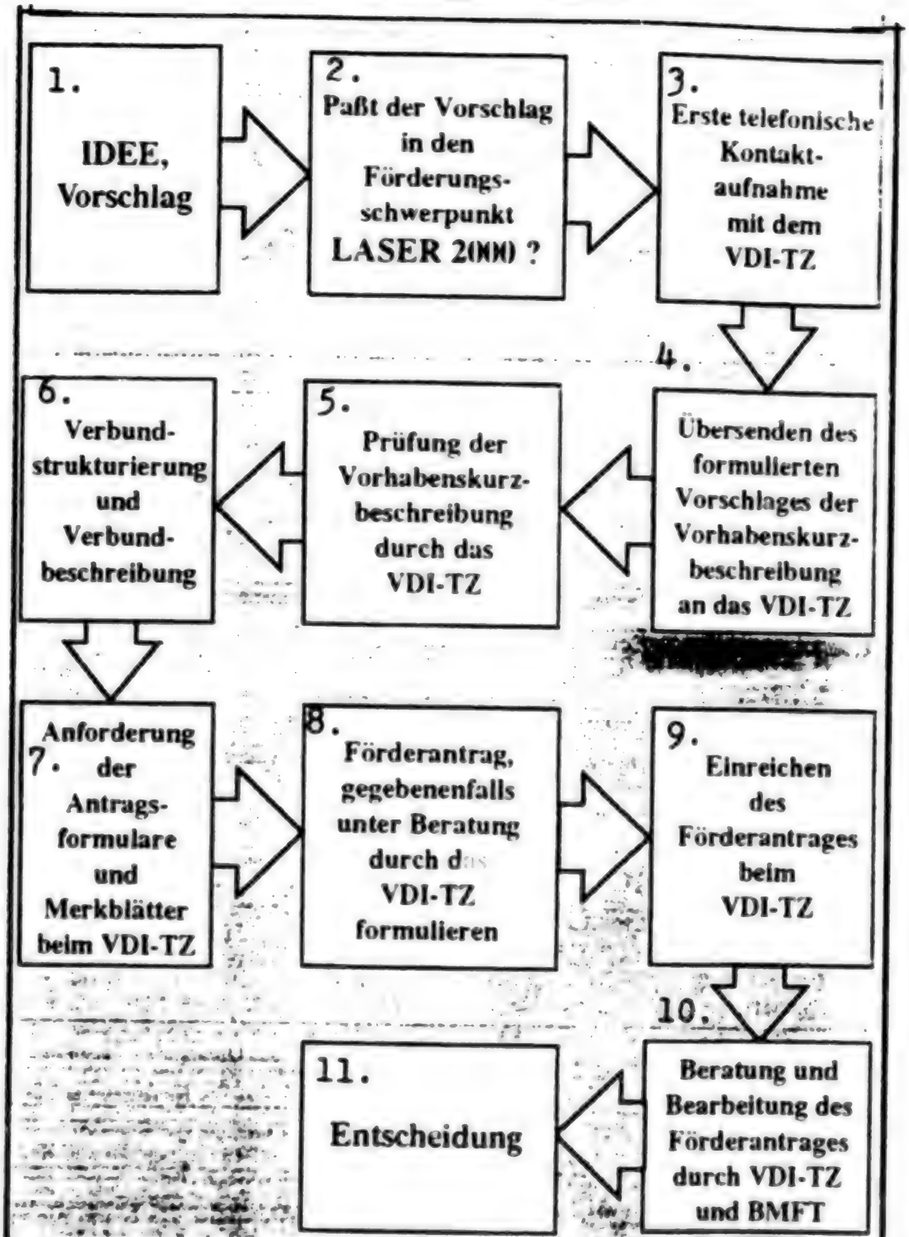

Fig. 22: Example of flow chart from project idea to subsidization decision (Source: VDI Technology Center, Duesseldorf)

Key: 1. IDEA, proposal—2. Does the proposal fit the LASER 2000 subsidy plan?—3. First telephone contact with the VDI-TZ—4. Transmittal of formulated proposal for brief project description to VDI-TZ—5. Testing of brief project description by VDI-TZ—6. Group structuring and group description—7. Request for application forms and information sheets from VDI-TZ—8. Formulation of subsidy application, possibly after consultation with the VDI-TZ—9. Handing in of subsidy application to VDI-TZ—10. Consultation and processing of the subsidy application by VDI-TZ and BMFT—11. Decision

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The project representative at the VDI Technology Center will also give hints for applicants (Fig. 22). Before applying for subsidization of R&D projects, the project representative should be consulted, e.g., to explain whether the project fits the LASER 2000 subsidy objectives, whether the requirements for a subsidy exist and whether the grant conditions can be met.

Further information about subsidy possibilities and consultation are found in a comprehensive brochure, "Advice On Research and Technology," obtainable from:

Publishing Group Deutscher Wirtschaftsdienst Marienburger Strasse 22 50968 Cologne Tel.: (0221) 37695-0 Fax: (0221) 3769517

APPENDIX

1. Further Subsidy Measures Involving Laser Research and Laser Technology

The Federal Republic, the Laender and the European Union (EU) support laser research and laser technology in many different ways.

BMFT programs and objectives include laser-specific measures related to the particular program and project goals, e.g., in medical research, photonics and biology. These activities are implemented either in cooperation with the laser target areas or with clear differentiation and harmonization (Fig. 23).

1.1 Cooperation and Harmonization With Other BMFT Target Areas

Cooperation is desirable and intended in those target areas in which laser and laser system developments and applications research complement each other synergistically. This is particularly true for the areas of

- laser medicine/minimally invasive therapy;
- laser biodynamics;
- lasers for environmental metrology.

Within the context of intensive harmonization processes, the requirements for further development e.g., of beam sources or systems are defined by laser users; from the side of laser research the potential of laser technology is brought into play. The cooperation ranges from the exchange of studies and convening of professional meetings to subsidization of joint projects (see Ch. 7).

Intensive harmonization and clear delineation exist in those target areas which support independent R&D projects in the laser field for the special purposes and goals of their programs (e.g., photonics, laser microsystems technology, large-scale apparatus for pasic research) or where R&D projects from other program fields could offer important facets for the further development of laser technology (e.g., material research, plasma technology).

- In photonics, diode lasers based on III/V semiconductorsare required for optical information transmittal

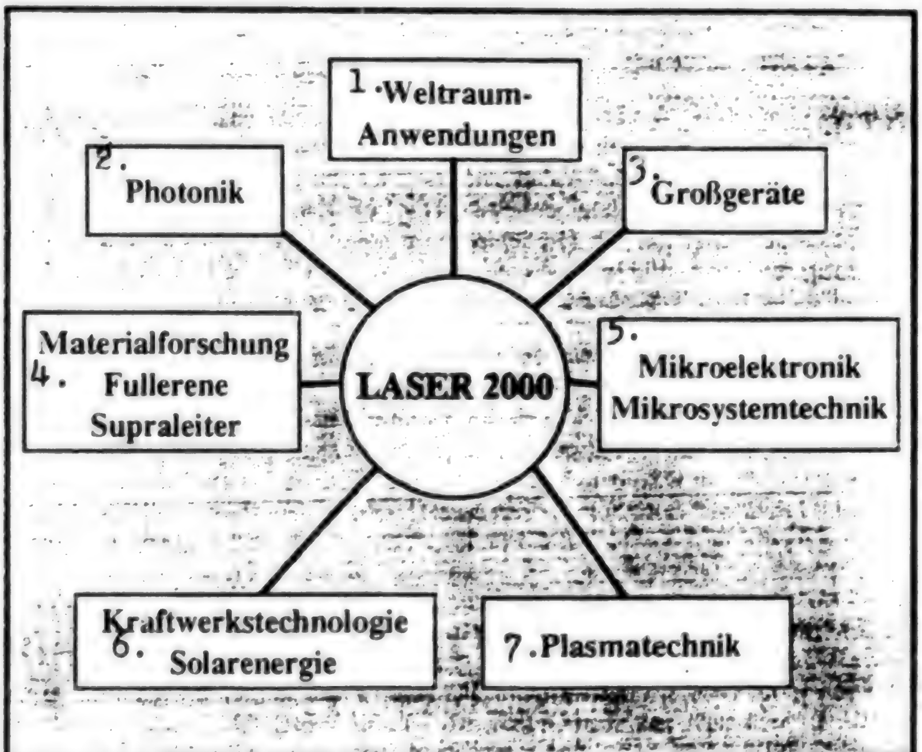

Fig. 23: Additional subsidy measures of the BMFT involving laser research and laser technology (source: VDI Technology Center, Duesseldorf)

Key: 1. Space applications—2. Photonics—3. Large-scale apparatus—4. Material research, fullerenes, superconductors—5. Microelectronics, microsystems technology—6. Power plant technology, solar energy—7. Plasma technology

and processing. They are characterizaed by comparatively low initial power levels but high modulation frequencyies and band widths. In contrast, the R&D objectives in the new LASER 2000 subsidy plan for diode lasers consist of high laser power and significantly lower switching and impulse frequencies. Potential synergy effects of both programs (e.g., III/V base technology) are being fully exploited.

- In microsystems technology the exploitation of the advantages of miniaturized components and their integration by structural and linking tehcnology is the center of interest. Thus it is reasonable to implement specific laser techniques while exploiting the potential of miniaturization technology in the microsystems technology program, participating in and adapting to the project. This applies, for example, to projects like "new sensors and actors for laser material processing," "ring lasers for microsensor systems" or "miniaturized diode-pumped solid-state lasers."
- For the purposes of basic research in the natural sciences, large-scale equipment-based on laser technology is also necessary, e.g., "free-electron lasers" (FEL) or the laser-supported gravity wave experiment (GEO). This large-scale equipment is used, for example, for investigations in atomic, molecular and solid-state physics (FEL) or to investigate cosmological questions (GEO). Synergistic effects such as the special development towards highly precise metrology using the diode-pumped solid-state laser for investigating gravitational waves are utilized to the advantage of both sides.
- In material research uses for laser technology can arise in the development of new materials (e.g., crystals for solid-state lasers). Conversely, new laser techniques are used in the manufacture, characterization and processing of materials with new properties in manufacturing and utilization.
- Important properties of gas lasers (CO_2, CO and excimer lasers), such as higher power and beam quality, can be improved by more recent developments in plasma technology (high-power gas discharges). The transfer of knowledge between the two areas is organized on the project level.

In addition, laser technology is used in numerous BMFT subsidy programs for their project goals, because certain problem and system solutions are only possible through the use of laser beam sources. This is true, for example, in the manufacture of high-temperature superconducting layers or fullerenes. But there are also programs such as microelectronics (deep UV lithography), solar energy (photovoltaic thin layer technology), and power plant technology (laser metrology for artificial flames), where commercial lasers are certainly used within the context of such projects, or available laser developments are adapted to project goals.

For space applications (e.g., satellite communications via solid-state lasers, climate and atmospheric research using lidar), in general the necessary lasers are not commercially available and cannot be produced by modifications for these applications. Here special developments are necessary which take into account the specific requirements in space.

1.2 Subsidy Measures of the Laender

Since the mid-80's some in the Laender have made efforts, some of them significant, to build up a regionally balanced research infrastructure in the area of laser technology. The Max Planck Institute for Quantum Optics in Garching, the Fraunhofer Institute for Laser Research in Aachen, the Institute for Technical Physics of the DLR in Stuttgart, and in the new Laender the Fraunhofer Institute for Material Physics and Layer Technology in Dresden and the Max Born Institute for Nonlinear Optics and Short-time Spectroscopy, the Blue List facility in Berlin, were created within the framework of joint research subsidization by the Federal Republic and the Laender in accordance with Article 91b GG.

In addition, the economic departments of the individual Laender have usually founded non-university research institutes (socalled "ancillary institutes") and financed them by means of seed funding or project subsidization. For the Laender, these would include the Hannover Laser Center (LZH), the Bremer Institute for Applied Beam Technology (BIAS), the Solid-State Laser Institute (FLI) in Berlin, the Laser Medicine Center (LMZ) in Berlin and the Institute for Laser Technologies in Medicine (ILM) in Ulm. In some colleges fairly large centers for laser research were created by the Laender, as for example in Duesseldorf, Erlangen and Stuttgart.

The Federal/Laender institutions mentioned above were thus complemented by other institutes which were also oriented towards industrial R&D projects; this is also expressed by the cooperation of industry in founding and financing the ancillary institutes.

1.3 Subsidization by the German Research Community (DFG)

The DFG supports basic research on some specialized topics of laser science using four concrete measures:

- target program "Steel-Material Interaction in Laser Beam Processing;"
- pecial research area 349 (Stuttgart): Highly Dynamic Beam Direction and Beam Formation Apparatus for Spatial Processing with Laser Beams;
- special research area 94 (Goettingen): photochemsitry with lasers;
- research group: non-toric laser optics (Aachen).

At present the DFG is making approximately DM7.5 million annually available for these predominantly knowledge-oriented research projects.

1.4 Subsidization by the Commission of the European Union

In the third framework program of the European Union (EU) for 1990-1994, undertakings in laser technology are

basically subsidized in the "Program for Research and Technological Development in the Area of Industrial and Material Technologies" (BRITE-EURAM). In this program the EU is pursuing as the particular goal of joint research the strengthening of scientific and technological basis for European industry, particularly in strategic areas of key technologies, and of support for industry to make it competitive on the international level.

Within BRITE-EURAM, projects concerning laser technology are concentrated in area 2, "Planning and Manufacture." Here the EU is setting the following goal:

- The development of innovative tools and technologies for qualitatively excellent and favorably-priced manufacturing systems to improve process control and increase precision and processing speed as well as integrating new processing technologies with traditions production methods.

The research tasks being implemented are:

- development of favorably-priced manufacturing processes like cutting, machining, grinding, reforming, fitting and gluing to increase productivity, quality and precision;
- development of favorably-priced high-energy beam methods, light wave guidance for beam production systems and the acoustic and optical testing procedures associated with them.

Bascially, at present approximately 5.5 percent of funding for these tasks, i.e.. approximately 17.5 million ECUs yearly, are made available by the EU for projects involving laser technology. Thus an application area is covered which is important, but relatively limited in comparison to the wide potential for laser use. The potential of the projects implemented in Phase 2 of BRITE-EURAM is three-quarters economic; i.e., they aim at new markets and/or improvements in productivity. In the fourth framework program for 1994-1998 the EU measures in BRITE-EURAM are to be continued, focussing on "new industrial applications of laser technology."

In other EU programs, very few projects relevant to measures in LASER 2000 are implemented. One worth mentioning is the program "Measurement and Testing" (BCR), in which lasers are used or developed essentially for metrological purposes (particularly gauges and standards).

EU subsidization of laser projects serves in part to complement the measures of the LASER 2000 subsidy plan—even from the viewpoint of subsidiarity—particularly in cases where cooperation across boundaries seems advisable for industrial development projects.

There is an intensive exchange of information between the EU and the Eureka technology program on the subsidization of laser projects: votes are taken within the framework of the Eurolaser Governmental Coordinating Committee (GCC), in which the General Management XII of the EU Commission is represented as a member. In a regular cycle of about two years the EU organizes a conference for all partners in EU and Eureka laser projects along with the current host country (in 1993, Germany).

2. Contribution of Federal Republic/Laender Research Facilities in the Area of Laser Research and Laser Technology to the Subsidy Plan

Through institutional subsidization of non-university research facilities, the BMFT, together with the Laender where they are located, supports laser research and laser technology for target areas oriented towards applications and towards basic research. In particular, the applications-oriented institutes of the Fraunhofer Society and the major research facility of the DLR are integrated into the activties of this subsidy target area. Of particular interest are:

- Fraunhofer Institute for Laser Technology (ILT), Aachen—project target areas: laser material processing, laser beam sources, laser systems technology and laser metrology;
- Frauhofer Facility for Material Physics and Layer Technology (IWS), Dresden—project target areas: surface processing with lasers, laser-thin layer technology and materials research aspects;
- Institute for Technical Physics (ITP) of the DLR, Stuttgart—project target areas: high-energy lasers and their applications, solid-state laser technology.

A significant part of the basic funding of the ITP of the DLR is raised from resources of the Federal Department of Defense for its specific departmental projects.

Further institutes supported by the Federal Republic and the Laender are mainly working on target areas of laser research oriented towards basic research. These include principally:

- Max Planck Institute for Quantum Optics (MPQ), Garching—project target areas: light-material interaction, new laser systems and their use in spectroscopy, chemistry, plasma physics and quantum optics;
- Blue List facility, Max Born Institute for Nonlinear Optics and Short-time Spectroscopy (MBI), Berlin—project target areas: short-time spectroscopy in clusters and boundaries, strong laser fields and excited states, nonlinear optical processes in condensed material.

In laser research and laser technology, overall the Federal Republic of Germany, with these Federal Republic/Laender research facilities, including the college centers and ancillary institutes built up by the Laender (see Appendix 1.2), has at its disposal a research infrastructure which is extensive in terms of comparisons with other countries and which covers nearly all aspects of laser technology. Its research fields and staffing must be

adapted to the requirements and sales of the laser-manufacturing and laser-using companies of the business economy. Since significant parts of the institutes must be financed by industrial contracts, there is a rough order of magnitude for the final development of this state research infrastructure. But within the context of such considerations and of the saturation trends of external contractual research now becoming evident in the market, there is no need for further creation of institutes by the Federal Republic at this time within the context of joint research subsigization in accordance with Article 91 b GG. Existing facilities must adapt themselves in size to the limited state possibilities for basic funding and get the rest of their funding from third parties, particularly from industrial contracts, even more than before. This also brings about a contribution to technology transfer from science to business.

3. Glossary

Adaptronic laser technology: Self-evaluating and self-regulating optical systems for the automatic adjustment of laser beam parameters.

All solid-state concepts: Laser systems which are built up completely out of solid-state components, particularly with the use of diode lasers or diode-pumped solid-state lasers, also nonlinear-optical components.

ASE: (Amplified Spontaneous Emission) Radiation emission in laser-active mediums of very high amplification which leads to laser activity without optical feedback, i.e., without a resonator.

Eye-secure lasers: Lasers whose radiation present no health risks for the human eye (see DIN VDE 0837).

Population inversion: The production of laser radiation is achieved through a transition between two energy levels in the laser-active medium. The laser effect, i.e., the light amplification through stimulate emission of radiation, requires an overpopulation of the higher energy level compared to the lower. The production of this overpopulation is called "pumping."

Carrier systems: Carriers which transport molecules of molecular compounds to the desired location in the human body, where they may selectively multiply.

DFB: (Distributed Feedback) Kind of optical feedback in the DFB laser, which is distributed over the whole length of the resonator structure.

Diode-pumped solid-state laser: Solid-state laser whose active medium is not stimulated by flashlamps, but by diode lasers (see laser).

Dosimetry: Determination of the necessary light intensity and light distribution for a desired effect in tissue. Particularly, the scattering properties of the tissue and the depth of light penetration associated with them play an important role.

Thin-layer technology: Production of layers with a thickness of less than or equal to 10 micrometers.

Tunable laser: Laser whose emission wavelength ("color") is continuously changeable over a limited range. Dye lasers are particularly popular for scientific applications. In future "all solid-state concepts" will predominate.

'Linking mechanisms: Interaction of laser radiation in striking material.

Excimer laser: Gas laser (see laser) with inert gas halogenides ("excited dimers," typically XeCL, KrF, ArF) as laser medium. The laser radiation is emitted in the ultraviolet range (typically 308, 248 and 193 nm).

Dye laser: Laser with dyes as active medium (see laser).

Color center laser: Optically pumped laser with broad absorption and emission bands. The active medium consists of color centers which represent distortions in the alkali halogenide crystals.

Solid-state laser: see laser; active medium is usually doped crystals (neodymium-YAG laser, etc.).

Fluoroscopy: Fluorescence spectroscopy, contains diverse analystical methods. Diagnostic method in medicine, e.g., to identify tumors.

Free electron laser: (FEL) Laser type in which the laser-active medium is formed from a highly energetic electron beam. Usually the path of the electrons is modulated in a periodically altered magnetic field, thus producing radiation emission.

Frequency conversion: Change (transformatio) in the frequency or the wavelength of electromagnetic radiation with the help of physical effects, particularly those of nonlinear optics.

Gas laser: Laser type (CO_2, HeNe, excimer, etc.) whose function is based on the excitation of a gas. Generally the excitation energy is provided in a gas discharge (electrical energy augmentation). Optical excitation or gas-dynamic excitation are also possible.

Semiconductor laser: The semiconductor laser is made up principally of a semiconductor crystal (gallium arsenide, etc.) with a pn junction which is forward-biased. Population inversion is produced through electrical current in the semiconductor.

High-power diode laser: Special form of the semiconductor laser to achieve maximal optical initial power levels and radiation intensity. High-power diode lasers are constructed as arrays (consisting of several laterally coupled stripe wave devices), parallel arrays (side-by-side arrays) or stacks (parallel arrays set up one above another).

Holographic Optical Element (HOE): Optical imaging elements which can provide an error-free image for a wavelength and an object point with a single optically

active surface. HOE's find applications e.g., as single or multiple beam dividers, glass fiber linkage optics and in multifocusing.

Injection laser: Injection of narrow-band laser radiation from an external source (master laser) into a second laser (slave laser) forces the latter to have the same emission behavior as the master laser (see laser).

Intensity: Laser beam power per surface element.

Interferometry: Metrology which is based on the coherent superposition of electromagnetic radiation.

Interstitial laser applications: Processes in which laser light is linked to the tissue (e.g., tumors) by thin optic fiber probes. The tissue is devitalized and/or coagulated in the process by the thermal effect.

Coherent light: A beam of light whose individual wave features oscillate in phase, i.e., are linked with another. A high degree of coherence is one of the special properties of the laser beam in contrast to conventional light sources.

Tailoring: Deposit of epitaxial semiconductor layer of a diode laser on a cooling body and application of electrical connections.

Laser: (light amplification by stimulated emission of radiation) Equipment for the production of coherent bundled light on the principle of light amplification through stimulated emission of radiation. This principle can be exploited in various laser-active media (gas, doped solid-state, etc.).

Laser high-speed layering: High deposit rates (at least $10^{-3}cm^3/s$) designed to use the method of laser particle deposition; this corresponds to a layer growth rate of 100 nm/s over 1 dm^2.

Laser ablation: Removal of atoms, molecules and/or clusters from the surfaces of solids or from biolgical tissue by means of focused laser radiation by non-thermal ablation.

Laser biodynamics: Interaction of laser light with biological systems for analysis, diagnosis or micromanipulation.

Laser chemistry: Controlled chemical reaction induced by laser radiation.

Laser-induced manufacturing procedures: Manufacturing procedures whose characteristics (flexibility, result of processing, etc.) are determined by the properties of the laser or laser beam.

Laser short-time metallurgy and heat treatment: Optical-thermal interaction of laser radiation with short duration which leads to structural changes in the material treated

Laser Particle Deposition (LPD): Layer formation on a substrate through particles (atoms, molecules, clusters) which are pulverized by a target by means of focused laser beams.

Maser: (Microwave Amplification by Stimulated Emission of Radiation) Equipment for the production of coherent microwave radiation; see laser.

Metrological reference object: Standard of comparison in metrology.

Microprocessing: Exact, low-tolerance processing in the micrometer range.

Minimally Invasive Therapy (MIT): Therapeutic procedures which protect the patient ("gentle operations").

Mode locking: Procedures to produce ultrashort light pulses in the picosecond and femtosecond range.

Necrotization of tumors: Killing (devitalization) of tumorous tissue through thermal or toxic intervention.

Nonlinear optics: In the high light intensity range classical optics become nonlinear optics. Examples of nonlinear optical effects include frequency doubling and frequency mixing.

Nuclear Magnetic Resonance (NMR): Diagnostic procedure based on the interaction of the nuclear spin of specific atoms (H-NMR, C-NMR, etc.) with a high-frequency field and a strong external magnetic field. In medicine, NMR can be used in connection with imaging procedures to represent tissue structures.

Optical biosensors: Serve to identify biological reactions or biologically relevant molecules, generally using optic-fiber-supported optical identification methods.

Optical pincers: Microscopically strongly-focused laser beam which holds movable cells or cell parts in suspension using the light pressure distribution in the laser beam and thus makes them manipulable.

Optical tomography: Structural identification of tissue using purely optical techniques and layered image reconstruction.

Optical scalpel: Severing of tissue by a laser beam with simultaneous cauterization of vessels.

Parametric amplification: Procedure to transform the wavelength of a laser beam into radiation with a longer wavelength, often with tunable wavelength, with the help of a nonlinear process in optical/nonlinear materials.

Phase conjugation: Optical method of controlling and changing the wave fronts in an electromagnetic radiation field. Phase conjugation is employed in laser technology particularly to improve beam quality.

Photons: Light quanta, colloquially light particles.

Phototoxic reactions: Chemical modification of molecules by the use of quantum energy of laser light. This can produce, for example, reactive oxygen molecules or other toxic compounds which can destroy cells.

Polarization: Orientation of the oscillation levels of electromagnetic waves.

Process analysis: Analysis and control of physical/chemical processes.

Quantum optics: Field of optics which, unlike wave optics, includes all optical phenomena which require the assumption of the existence of photons as quanta of the electromagnetic readiation field in order to understand and interpret them.

Rapid prototyping: Flexible and rapid production of models and protypes from paper, plastic, metal or ceramics.

Resonator: Resonance structure in a laser, in which, for example, with the help of two mirrors the laser light produced in the active medium is directed through it several times, and thus amplified and decoupled.

Restriction enzymes in genome analysis: Enzymes which are capable of splitting the DNS (genome) at defined points.

X-ray laser: Laser with emission wavelengths in the X-ray range. Of particular interest is the wavelength range from 2-4 nm, the socalled "water window," since the absorption of hydrogen and carbon atomes is very different at this level and thus the investigation of biological tissue is possible in absorption photography.

Ruby laser: Special type of solid-state laser which emits red light. The active medium is a ruby crystal doped with chromium ions.

Sensitizer: Molecules (usually fluorescing dyes) which absorb the quantum energy of laser photons and transfer them to oxygen molecules for a phototoxic effect.

Soliton laser: Special types of solid-state lasers in which certain optical properties of the laser-active medium are exploited to produce ultrashort (fs) laser pulses. Solitons are stable ultrashort pulses.

Spectroscopy: Photography and interpretation of spectra; general category for a number of analytical methods of identification, i.e., methods which act selectively on materials.

Squeezed states: Extremely low-noise laser light which is produced by a nonlinear process.

Beam quality: Quality of laser light, which is determined by the product of the magnitudes beam divergence and beam diameter: the smaller the product, the greater the beam quality, and thus the focusability of the laser beam.

Up-conversion systems: Laser whose upper laser level is pumped by a 2-photon process. Thus the laser wavelength becomes shorter than the pumping wavelength.

4. Bibliography

Sources Cited in the Text:

[1] M. Reinhard: "Stand und wirtschaftliche Perspektiven der industriellen Lasertechnik in der Bundesrepublic Deutschland" ("Status and Economic Perspectives for Industrial Laser Technology in the Federal Republic of Germany"), IFO Institute for Economic Research, Munich 1990.

[2] M. Eyett: "The Market in Revolution," PROGNOS TRENDLETTER 2/92, p. 8, Basel 1992.

[3] G. Herziger: "Die Situation der Lasertechnik in der Bundesrepublik" ("The Situation of Laser Technology in the Federal Republic"), Aachen 1991.

[4] P. Wirth: "Working Group on Lasers for Material Processing in the VDMA: Situation and Future Market Requirements From the Viewpoint of the Manufacturers of Laser Technology Products, Expert Discussion on 15/10/1990 in Bonn." IFO Institute for Economic Research (ed.), Munich 1991.

Further Sources

"Evaluation of the Subsidization of Laser Research and Laser Technology with BMFT Funding: Analysis of Effectiveness of Subsidy Instruments," Battelle Institute e.V., Frankfurt, August 1991 (Study commssioned by the BMFT, FKZ 13N 5692).

"Memorandum on Extension of the Research Subsidization of the BMFT in the Field of Laser Technology," Working Group on Lasers for Material Processing in the VDMA, May 1991.

Position Paper of the FuO Association on the Extension of the Subsidization of Laser Research and Laser Technology by the BMFT," FuO Association, August 1992.

Measures for the Dissemination of Laser Technology in the Federal Republic of Germany," memorandum of the Scientific Working Group on Laser Technology (WLT), February 1991; supplement to the WLT memorandum, Febuary 1993.

"Memorandum on Research Subsidization of Laser Technology in Medicine," Working Association of German Laser Medicine Centers (ADL), February 1991.

"Laser-supported Metrology, Measures for the Dissemination of Laser Technology in the Federal Republic of Germany," Laser Metrology Working Group, July 1991.

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